

**European chemical forum**

**B**ARCELONA served as a fitting forum on which the economic prospects of the European chemical industry were discussed, at the recently held 32nd International Congress on Industrial Chemistry (which we are fully reporting in this issue). A significant aspect of this congress was the American participation—in fact, the American delegation was almost entirely represented by senior executives of leading U.S. chemical and plant manufacturers. In order to underline American chemical interests in Europe a special 'American Day' at the congress was devoted entirely to the impact of the American chemical industry on Europe in the 1960s.

Well to the fore in these deliberations were the market researchers—a modern equivalent of the soothsayers of yore. In the U.S., market research has become increasingly important to any manufacturer contemplating expansion into spheres other than the ones with which he is particularly familiar. At present American market research teams are extending their activities to Europe, both in order to help European chemical manufacturers to widen their markets as well as to determine what the eventual relationship of the American chemical industry will be *vis-à-vis* the E.E.C. and the E.F.T.A.

An interesting survey of European chemical markets was presented at this 'American Day' by D. J. Spence, of Roger Williams Technical & Economic Services. According to this survey, European chemical exports represent a very substantial proportion of the total chemical output; with Germany exporting 27% of her production, the U.K. 20%, France 10%, Holland 50% and Belgium as much as 55%. Although a sizeable proportion of these exports are to the under-developed countries, the industrial areas are still taking a growing proportion of exports whilst the non-industrialised areas are taking a diminishing proportion. This disturbing trend has several causes. Under-developed countries are desperately striving to improve their standard of living by setting up local industries and reducing imports. It does not follow from this that the total imports of such countries decline but the pattern of import requirements alter. Generally an under-developed country seeking to industrialise itself will select those industries most suited to its immediate requirements, such as textiles and textile finishes, agricultural chemicals and dyestuffs—it is often a matter of prestige for such countries to become self-sufficient in fertiliser production without any regard to economics. On the other hand, there will be some reluctance to embark on a programme to manufacture such products as soda ash which is a heavy user of capital and a relatively poor user of labour. Hence it can be argued that

European exports of heavy organics and inorganics have the best possibilities in under-developed countries. The survey points out that small countries with a high European-type standard of living, such as New Zealand, do not subscribe to this philosophy and are likely to continue to import most European chemicals.

What is the position of European exports when related to competition from the eastern bloc? Many European companies are supplying chemical plant to Russia, for example Courtaulds who are supplying a rayon, acetate and acrylic fibres plant, and B.A.S.F. of Germany who are supplying technology for an acetylene-from-natural-gas plant. It is easy, as the survey points out, to deprecate technical achievements in Eastern Europe and to argue that exports from these countries are made regardless of cost. It cannot be denied that the rate of industrial development in these countries has risen very rapidly since the war and that it may well be that these countries are making profits even when exporting goods at lower prices than those of their European competitors. It may thus be quite possible that much capital can be accumulated in Eastern Europe for investment in industry at a rate that seems quite impossible in Western Europe.

It seems clear from these surmises that the U.S. will find it increasingly important and vital to participate actively with both the E.E.C. and the E.F.T.A. in chemical production and exports. The indication is that more and more agreements between individual American firms and European combines are being drawn up—the U.S. will probably wish to have a foot in both E.E.C. and E.F.T.A. camps and this should be to the advantage of all parties concerned.

**Sea-water distillation**

**T**HE Home Secretary officially opened a £257,000 sea-water distillation plant in Guernsey recently. This plant is the first of its kind in the temperate zone—and in a country with an adequate rainfall. Therefore it will be regarded with special interest by water engineers, since the problem of producing adequate fresh-water supplies is becoming increasingly complex because population figures almost everywhere are rising. Thus in Britain water consumption has reached a national level of 60 gal./day/head (not including water used for industrial cooling). In the U.S. the figure is 110 gal./day, and in many other parts of the world underground water supplies are now used up faster than they are being replenished.

Cost is usually the critical factor in determining whether or not a distillation unit is warranted. Analysing costs involved in the Guernsey plant, the manager of the States of Guernsey Water Board stated that the total cost of the plant including the necessary sea-water

intake and pipelines is estimated at £257,000, or rather less than one-third of the capital cost of storage. There is an added advantage that water can be produced from the sea whatever the weather conditions, whereas with prolonged drought the storage once used would not refill.

The distillation process takes place in an evaporator 69 ft. long, 19 ft. wide and 18 ft. high, which is internally sub-divided into a number of flash and preheater chambers. The incoming sea-water passes through heat exchangers, after which it is further heated by exhaust steam from a steam engine. In the flash chambers the atmospheric pressure is reduced by means of an air ejector and the hot sea-water flashes off salt-free vapour due to this partial vacuum. The vapour is condensed on the heat exchangers as pure distilled water which is collected and pumped to storage. De-aeration of the incoming sea-water and chemical injection equipment ensure that corrosion and scale formation are kept down to a minimum, enabling the plant to be run for long periods. The control equipment and switchgear for the whole plant is housed in the control room adjacent to the boiler house. The panel carries all the indicating and recording instruments required, and also an audible and visual alarm to indicate a rise in salinity of the distillate to 100 p.p.m., in which case the distillate is automatically discharged to waste.

The operating cost of the new plant is estimated to be about 7s./1,000 gal. or £14,000 for an average year's working. Taking this together with capital charges based on a 20-year life for the evaporator plant, the total annual expenditure will be £33,000, which is only about one-half of the loan charges and running costs of a storage scheme.

### ***Fast breeder reactors—are they economic?***

SUFFICIENT experience is not yet available to determine accurately the capital cost of large breeder reactor power plants. It is generally expected that such installations should prove more expensive than most thermal reactor power plants because the reactor and sodium systems are more difficult to construct. Similarly, circulating fuel power reactors are assumed to be more costly because of the complexity of the piping systems and special provisions required to permit remote maintenance of the various systems. It is accepted, however, that a somewhat higher capital cost can be tolerated in breeder reactors because of their potentially lower net fuel cycle cost. Still higher capital costs can be tolerated by those reactors which also achieve high thermal efficiency and fast reactors have the inherent capability of operating at very high thermal efficiencies (which is mainly due to the thermal properties of the preferred coolant, sodium, having excellent heat transfer properties and a boiling point above 1,600°F.). Steam conditions comparable to the most efficient fossil fuel plants should be easily attainable and without pressurisation of the reactor system.

It is well known that the minimum critical mass of a thermal reactor is less than 1 kg. of fissionable material,

whereas the critical mass of a fast reactor is several tens of kilogrammes. There has been some tendency to rate fast power reactors low in specific power because of the high enrichment of the fuel in the core. The fast reactor can utilise plutonium more efficiently than any other reactor type—this is not confined to the plutonium-239 isotope, but includes those isotopic mixtures produced by high burn-up in thermal reactors. In addition, the fast reactor also utilises the depleted uranium by-product from isotope separation plants and the recovery of low enrichment thermal reactor fuels. It therefore becomes an efficient consumer of the two major by-products of the nuclear industry.

The price of various materials which can be utilised and produced in a fast reactor is difficult to predict, since a free market price for plutonium and depleted uranium is somewhat difficult to assess at this time. It is expected that, as these materials become more and more abundant, fast reactors will enjoy a somewhat monopolistic position with respect to their use.

### ***Oil and petrochemicals in Italy***

ITALY'S industrial output is now nearly three times as big as the pre-war volume. In line with developments in other spheres Italy has experienced a steady growth in consumption of energy—although this still lags behind that of her neighbours, with a *per capita* consumption of 1 ton coal equivalent per year compared with 2.5 tons for the European Common Market countries and 4.5 tons for the U.K. This relatively low use of energy is unfortunately connected with the lack of indigenous fuel resources, hence the intense efforts which have been devoted to seeking oil in Italy since the end of the war. Following the discovery of natural gas deposits in the Po valley in 1944 efforts were intensified; however, the first major oil find did not occur in the mainland but in Sicily. Despite all efforts, mainland oil output is still almost negligible and Sicilian production at present provides almost all of Italy's indigenous oil.

In contrast to this, the oil refining industry, which has also been established since the war, is quite formidable. In terms of overall capacity, Italian oil refining industry at present ranks eighth among the oil refining countries of the world. An important adjunct to this refining industry is the manufacture of petrochemicals (a total investment of £60 million), as a result of which Italy provides about one-sixth of all European-produced petrochemicals. Italy quite naturally, is now anxious to expand her activities in the oil industry by developing production overseas. A step in this direction was the acquisition of a concession in Persia. Similar concessions have also been obtained in Tunisia, Morocco and Libya. Success in any or all of these ventures should add considerably to Italy's economic health, besides giving added inducement to the government to encourage a higher rate of oil usage through reduction in the present level of taxation which, incidentally, makes petrol dearer in Italy than anywhere else in Europe.

## Nitroso rubber

A NEW type of rubber which is not only flameproof but will extinguish flames was recently described at the American Chemical Society's 138th national meeting held in New York, in a paper given before the Division of Rubber Chemistry. Dr. J. C. Montermoso, who presented the paper, mentioned that this rubber, called nitroso rubber, has interesting properties; it is resistant to many solvents and a wide variety of strong chemicals and remains flexible down to  $-40^{\circ}\text{C}$ . The fact that it is also quite resistant to sunlight and ozone indicates good storage characteristics.

The skeleton of the molecular structure of nitroso rubber differs from that of other elastomers because instead of being composed entirely of carbon it is made of carbon, oxygen and nitrogen. A new vulcanisation system had to be developed because nitroso rubber does not respond to the conventional sulphur used in natural rubber nor to the metallic oxides which cross-link neoprene and *Hypalon* elastomers. Amines and their derivatives, however, were effective in vulcanising nitroso rubbers and fine-particle silicon dioxide was found to be the most promising reinforcing filler.

The physical properties of the vulcanised rubber, as illustrated by its low tensile strength of 500 p.s.i. and ultimate elongation of 500%, limit its immediate application. It is felt, nevertheless, that continued compounding studies should result in a vulcanised rubber with improved physical properties.

## Corrosion hypothesis

THE mechanism of corrosion has been the subject of much speculation; it is agreed by most physical chemists that this is most complex and, although much more about it is understood nowadays, interesting hypotheses are still propounded.

In a series of experiments recently carried out at Westinghouse Research Laboratories, pure iron wires were reacted with oxygen and water vapour under closely controlled conditions at  $835^{\circ}\text{F}$ . It was found that with dry oxygen the iron forms a protective oxide coating from which grow billions of tiny round oxide whiskers less than one-millionth in. in diameter and 30-millionth in. high. Each whisker was found to grow from a single specific growth site on the surface of the wire. When the wires were reacted with water vapour a marked difference was noted. Thin, pointed, blade-shaped platelets of iron oxide erupted from the growth sites, gradually spreading across the metal surface. These were one-millionth in. thick, 30-millionth in. wide and 300-millionth in. high. As they grew in size they were found to spread more than 50 times in area over the sites observed for dry oxygen alone, reaching a density of nearly one billion/sq.in. of surface area. The amount of iron rust they represent is 250 times that which forms when the water vapour and the hydrogen ions released are absent from this reaction. It was shown that less than one part water vapour in 200 parts dry oxygen atmosphere will initiate crystal growth.

It can be assumed as a result that hydrogen ions in the water vapour enlarge the areas of chemical reaction between oxygen and iron to bring about greatly increased corrosion rates. At lower temperatures this basic reaction is masked and complex corrosion products formed are unstable, so that the corroding metal is often removed from the reaction site. This possibly represents a new insight into the mechanism of corrosion, since two control measures must be considered in addition to any electrochemical effects that are involved in rusting: (1) hydrogen must be prevented from entering the metal and (2) the growth of the localised reaction sites must be inhibited by addition of suitable alloying elements.

## Alchemical engineering

ON a recent visit to Spain we noted with interest that one of the main indigenous chemical raw materials is still mercury. This metal occurs in the form of its sulphide and is known in that form as cinnabar. Although some progress in the efficient extraction of mercury from cinnabar has been stimulated by increased demands for this metal, traditional methods are still used in which the red ore is roasted in a furnace and mercury together with sulphur dioxide are volatilised.

Present-day production of mercury from cinnabar has strange connections with the alchemists of the Middle Ages. One of the main tenets of alchemy was that all base metals could attain the noble state of gold by addition of the philosopher's stone, which acts somewhat like a catalyst in bringing about such transmutation. This stone was often described as a red powder, and was assumed by some to be the red ore, cinnabar. It seems possible that decomposition of cinnabar into mercury and sulphurous fumes may have led Muslim alchemists to propound the well-known 'sulphur-mercury theory' of the origin of metals (often attributed to one of the most famous Arabian alchemists, Jabir Ibn Hayyan, known to the Western world as Geber, who lived in the 8th century). According to medieval alchemical theory, when the impure metals sulphur and mercury were conjoined in natural processes under planetary influences, they gave rise to base metals such as tin and lead. When they were of high purity they gave gold or silver and when each of these metals was of superfine purity they yielded the philosopher's stone. As an outcome of the sulphur-mercury theory it was often supposed by adepts that the 'seeds' of gold and silver could be extracted from these noble metals in the form of 'sophic' sulphur and 'sophic' mercury. These seeds could then be combined to yield the philosopher's stone.

According to these views, an initial quantity of gold was required in order to effect transmutation. The stone could then be used in converting base metals into more gold so that the original gold was 'multiplied'. One of the favourite metals for 'multiplication' was mercury. This choice has been curiously vindicated by modern observations that gold ( $Z = 79$ ) can really be produced from mercury ( $Z = 80$ ).



## Progress in chemical industry

MANY interesting statistics were revealed by Mr. S. P. Chambers, chairman of I.C.I., in a survey on the British chemical industry, published in the August edition of National Provincial Bank Review. Generally speaking, the expansion of the British chemical industry from 1953 to 1959 was greater than that of the American chemical industry but less than that of the chemical industry of the European Economic Community (the Six). The following table gives some interesting data comparing chemical production with industrial production. The figures in brackets refer to the percentage of the total chemical output of the Western world.

	Column 1	Column 2	Column 3
	Annual growth rate of industrial production, %	Annual growth rate of chemical production, %	Column 2 divided by Column 1
U.K. (7.3%) ..	3.5	5.6	1.6
U.S.A. (47.7%) ..	1.9	4.9	2.6
Canada (2.3%) ..	4.1	6.0	1.5
E.E.C. (21%) ..	7.8	11.5	1.5
West Germany (8.4%)	8.8	11.9	1.4
France (5.8%) ..	7.9	11.4	1.4
Italy (4.6%) ..	8.0	13.1	1.6
Japan (5.3%) ..	13.7	14.5	1.1

It can be noticed from this table that in the U.K. from 1953 to 1959 chemical production expanded faster than industrial production. The most important factor is that the growth of the chemical industry in the E.E.C. (and in the major countries it comprises) has been about twice as fast as in the U.K., U.S. and Canada. Even when industrial production alone is examined, the E.E.C. again shows up favourably (except by comparison with the spectacular growth of Japanese industry). The U.K., although showing a growth rate less than that of West Germany, France and Italy, has still progressed faster than the U.S. Mr. Chambers suggests from these figures that Britain has put up a performance over the last seven years that is neither brilliant nor depressing.

As regards the contribution of the chemical industry to exports, the survey points out that it is not always in the national interest for the chemical industry to export all it can. This is because it is essentially a service industry, in that most of its products do not go to the ultimate individual consumer but to other industries which have the right to expect a reasonable continuity of their supplies.

Finally Mr. Chambers alludes to the trade division in Europe between the Six and the Seven. 'One of the problems facing the chemical industry today', he maintains, 'is this country's expanding trade in Europe which will become increasingly difficult unless greater freedom of trade between these two groups exists. We must therefore try to avoid being elbowed out of the territory of the Six and must seize the opportunities which are offered to us by the lower tariff barriers between the Seven'. This sounds like having our cake and at the same time eating it. The trade division in Europe is becoming increasingly difficult especially for the chemical industry, and the sooner some *modus vivendi* is found the better for all concerned.

## Profits in whisky—and plastics

THE respective profit contributions of Scotch whisky and gin companies on the one hand and the industrial group on the other hand are of the order of 80% and 20%. This was reported by the chairman of the Distillers Co. Ltd. when presenting his annual statement recently. During the year 1959-60 the total value of the group's turnover exceeded £233 million, representing an increase of 11% over the previous year. It must be remembered that the industrial division of Distillers includes the chemical division, plastics division, biochemical division and food division as well as subsidiary companies like British Hydrocarbon Chemicals, British Geon, British Resin Products and Murgatroyd's Salt & Chemical Co. in which Distillers has a large interest.

The chairman's statement mentions that with the general revival in industrial activity there has been a substantial increase in the sales of all chemicals produced by the group. Three new plants were commissioned during the year—all for British Hydrocarbon Chemicals. The first plant is for the production of high-density polyethylene; the other two units are for the production of cumene and phenol. Both are already operating at full capacity. It is now planned to increase considerably the production facilities for butadiene, for which there is an increasing demand in the manufacture of SBR-type synthetic rubbers. A new plant to produce methanol has also been planned and an ethylene dichloride production unit is envisaged to help in the expanding manufacture of PVC. British Geon substantially expanded its PVC capacity and is increasing its production of *Hycar* synthetic rubber.

Thus, last year's indications of an increased demand for plastics, particularly for industrial applications, has been fully confirmed. The report ends on a wry note stating that 'the European Common Market poses a difficult problem which cannot yet be accurately measured but at least everything is being done to achieve the highest standards of efficiency in production'. Another pointer to the unease which industrial circles are beginning to feel at the bisection of the European market.

## Seasonal greetings

AS we come to the end of 1960 we should like to take this opportunity of wishing our many friends in all parts of the world a merry Christmas and a happy new year.

An excellent way of expressing your appreciation for kindness and help received from colleagues during the past year is by a gift subscription to CPE. This should serve as a constant reminder of your good wishes throughout the year. Subscription order forms can be obtained from the circulation manager, CHEMICAL & PROCESS ENGINEERING, 9 Eden Street, London, N.W.1. Prompt return of the completed form, accompanied by the subscription, will ensure that the recipient receives a regular copy of CPE throughout 1961.



# Flow Measurement Errors

By S. T. Bonnington,\* B.Sc., A.M.I.Mech.E., and K. J. Zanker,\* B.Sc.

*Research on pressure-differential methods, used in the measurement of fluid flow, is being carried out in many laboratories and is leading to a better understanding of the factors affecting accuracy. This article presents a survey of published information on the causes and magnitude of flow measurement errors for pressure-differential meters and describes the results of experiments carried out at the British Hydromechanics Research Association to develop a flow-straightening device which will enable the use of shorter lengths of approach piping.*

**ALTHOUGH** many flow-measurement standards exist, defining the accuracy and range of application of pressure-differential devices, they are based on comparatively sparse experimental data.

This scarcity of information results in three major difficulties:

(1) The standards proposed by different countries do not necessarily agree, and there is a tendency for certain standards to ignore particular methods of measurement owing to lack of experience.

(2) In all standards, recommendations on acceptable installation and tolerance on accuracy are conservative.

(3) There is a reluctance on the part of the authors of some standards to give guidance on the loss of accuracy resulting from failure to conform to the standard conditions.

This latter point is of especial interest in, for example, chemical plant, where the provision of suitable setting length is not always convenient and where the material being handled may cause changes in pipe roughness through corrosion or encrustation.

## Causes of error

The measurement of flow under discussion consists essentially of causing a change of velocity in a pipe by a constriction. The resulting pressure difference is detected by pressure tapings drilled in the wall of the pipe adjacent to the constriction, and is measured by a manometer or differential pressure gauge.

Errors connected with the measuring instrument can be detected by normal static calibration. It should be noted, however, that such calibrations do not reveal errors associated with pulsation of pressure within the pipe-

line. Such errors can be large, but are outside the scope of this survey.

The other principal error associated with pressure measurement is the influence of imperfections in the static-pressure hole in the pipe wall. These errors can amount to 30% of the mean velocity head, in extreme cases where drilling burrs are not removed.<sup>1</sup> Incorrect location of pressure tapings can also cause appreciable error. Errors connected with the constriction itself are discussed in detail below; apart from deviations caused by dimensional inaccuracy, the calibrations of orifices are dependent on the maintenance of a truly sharp edge, and the reading of a venturi will be affected by changes in the roughness of the converging section. Appreciable changes in calibration can also arise from imperfections in installation.

Probably the most widely studied errors are those associated with the influence of upstream conditions. The effects of disturbance of the velocity profile by pipe fittings have been well documented but, more recently, attention has been drawn to the need for more precise specification of the influence of pipe roughness.

All flow meters of this type have a discharge coefficient which is a function of Reynolds number ( $Re$ ), showing appreciable variation at low Reynolds number, but very slight variation at high  $Re$ . It is reasonable to say that these variations are accounted for by normal calibration, and the operating range of the meter can usually be selected to be within the turbulent régime where the variation of discharge coefficient is least. Thus this variation can hardly be described as an error, and will not be discussed in this survey.

The following survey outlines particular records of errors associated with the causes mentioned above, for orifices, venturi meters and the Dall-tube variation of the venturi.

## Orifice meters

Errors due to dimensional inaccuracy of orifice meters can be for the following reasons.

### (a) Rounding of upstream edge

This is probably more likely to occur after use in a gritty fluid than in manufacture. As would be expected, rounding of the edge increases the discharge coefficient; the most extreme value reported in reference 2 shows an increase of about 2½%. The magnitude of the error decreases as the area ratio ( $m$ ) increases, and as the pipe diameter increases.

### (b) Non-standard plate dimensions

It is usual to specify for standard orifices a maximum thickness of the plate, and a maximum length of parallel throat. Reference 2 reports that doubling the plate thickness is unlikely to cause errors exceeding 1% for moderate area ratios, but a similar increase in length of the parallel throat can cause a 2½% change in coefficient. The errors from the two causes are of opposite sign, and thus a simultaneous increase in both dimensions may be less serious than a change in one of the dimensions.

### (c) Incorrect location of pressure tapings

For installations where the pressure tapings are located one diameter upstream and one-half diameter down-

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stream of the orifice, errors in location within the normal engineering tolerances are unlikely to be serious. Possibly the most likely mistake would be a reversal of the spacings, and reference 2 reports errors of the order of 10% for moderate area ratios, increasing seriously as  $m$  increases.

Errors associated with installation of orifice meters are due to the following.

(i) *Orifice carriers and jointing material*

The practice of constructing an orifice plate with a carrier ring and a pressure-measuring annulus adjacent to the plate offers many practical advantages in interchange of meters. However, deviations of pipe bore cause difficulty in matching the orifice-carrier and pipe diameter, and errors of 5% from this cause are possible with moderate discrepancies in diameter (say 5%).

A similar protrusion of jointing material adjacent to the carrier is considerably more serious, and can change the discharge coefficient by 10% for an  $m = 0.5$ .

(ii) *Pipe layout*

As mentioned before, the requirements laid down in standard codes on flow measurement tend to be conservative. A useful summary is given by W. J. Clark<sup>3</sup> showing in all cases a substantial reduction in the required length of straight pipe between a pipe fitting and an orifice plate. For many types of fitting, the requirements suggested by Clark are 50% of those given in B.S. 1042.<sup>4</sup> Reference 3 also gives estimates of the correction factor to be applied if shorter straight lengths are used. For example, a further 50% reduction in length will in general require a correction of about 2% to the assumed discharge coefficient and, if 5% accuracy were acceptable, the necessary length becomes negligible. With respect to the use of a globe valve upstream of an orifice, experiments by Murdock *et al.*<sup>5</sup> are in general agreement with the recommendation given by Clark.

In general, the errors due to pipe layout increase as the orifice area ratio increases, but the reverse is the case when swirl is present, as it would be, for instance, following two adjacent bends in planes at right-angles.

(iii) *Pipe roughness*

In, for example, references 2 and 4, correction factors are given for pipe diameter, which can be regarded as showing the effects of roughness (*e.g.* B.S. 1042<sup>4</sup> applies to 'clean cast-iron

or mild-steel pipe'). These correction factors are modest, being only about 2%, even for small pipes and high orifice area ratios. Much greater variations of roughness are possible, especially in chemical plant, and experiments reported by Clark and Stephens<sup>6</sup> are a valuable beginning to a study of the problem. As an example of the extreme changes possible, roughnesses were formed by spheres 0.3 in. diam. in pipes of 3, 6 and 12 in. diam. For an orifice area ratio of 0.5, the corresponding errors were 16%, 10% and 6%, when allowance was made for the reduction of pipe diameter by the encrustation. If no such allowance was made, the errors were about 35%, 16% and 8% respectively.

Of great significance was the demonstration that the orifice coefficient was influenced principally by the roughness of the pipe within about five diameters upstream of the orifice, and that cleaning within this distance restored the orifice coefficient to the value corresponding to the original pipe.

Probably the ultimate development will be to establish the correlation between roughness effects on normal pipe-friction losses and the effects on orifice coefficient, but present information is not sufficient to achieve this.

### Venturi meters

The influence of dimensional accuracy of venturi meters has not been widely reported, but one case has been reported by Spencer.<sup>7</sup> In this meter, a discharge coefficient greater than unity was measured, and the cause was finally traced to a sudden enlargement in the throat (0.003 in. in a 3-in. throat) occurring at the junction between the two separate halves of the meter, and coinciding with the throat slot. A subsequent study of the influence of throat slot dimensions did not show any appreciable change in coefficient.

A series of experiments on the effects of changes of shape on the coefficients of venturis are reported by Schlag.

A change in the angle of convergence from 15° to 12° showed a change of 1% to 2% in the coefficient,<sup>8</sup> but changes in the angle of the divergent cone affected only the overall loss of the meter.

The influence of changes in the radius used in joining the convergent cone to both the upstream pipe and the throat has been measured.<sup>9</sup> As would be expected, the transition between the cone and the throat is of

greatest significance, and changes in coefficient of the order of 1½% are reported.

Except for low Reynolds number régimes, a change in throat length over the range from 0.1 to 0.4 throat diameter did not cause a serious change in coefficient.<sup>8</sup>

There are various influences of installation of venturi meters.

(a) *Pipe layout*

Probably the most extensive study of the effects of upstream disturbance is that by Pardoe.<sup>10</sup> Again it is evident that, except for the highest degree of accuracy, the code recommendations give a conservative figure for necessary settling lengths. It is interesting to note that two 90° bends in planes at right-angles, an arrangement likely to induce swirl, can result in a discharge coefficient greater than unity. A combination of this sort with very limited settling length (less than four diameters) also fails to conform to the usual characteristic, that error increases as area ratio increases.

Jorissen<sup>11</sup> has found that valves can be fitted within one throat diameter downstream of the throat of a venturi without serious influence on the coefficient. Such an arrangement could enable the use of smaller valve sizes than the nominal pipe bore, and the energy recovery of the meter is unlikely to be seriously impaired.

(b) *Pipe and meter roughness*

As with the orifice plate, code allowances for roughness are plotted as allowances for pipe diameter (assuming a constant wall roughness). A paper by Hutton<sup>12</sup> has outlined a rational approach to the prediction of roughness effects which gives a reasonable correlation of accepted code values for the variation of discharge coefficient with meter size. The definition of discharge coefficient of a venturi is based upon the mean velocities at the location of the upstream and throat pressure tappings.

The ratio of the actual kinetic energy at a section to that based upon mean velocity varies with the distribution of velocity, which is a function of the pipe wall roughness and Reynolds number. This difference between actual and nominal kinetic energy results in a small increase in discharge coefficient as the pipe wall roughness increases. Tests by Abramovitz<sup>13</sup> suggest that, as with orifices, cleaning of the pipe immediately upstream of a meter will bring the discharge coefficient down again.

Moderate changes in the roughness

of the converging part of the venturi are thought to affect the coefficient by changing the frictional losses between the upstream and throat tappings. In this case an increase in roughness causes a decrease in discharge coefficient, the change being of greater magnitude than that due to pipe roughness.

Thus, for a venturi installed permanently, where fluid conditions cause an increase in roughness with time, the meter coefficient will gradually decrease. The predictions of Hutton have agreed with tests reported by other workers, who demonstrated that the coefficient could be restored to its normal value by cleaning. Roughness effects have also been measured by Schlag<sup>14</sup> and Witte.<sup>15</sup>

### The Dall tube

A new development of the venturi which produces a greater differential pressure and causes less overall head loss than a similar standard design of the venturi is the Dall tube. Some of the improvement in performance arises from the use of abrupt changes of direction, entailing sharp edges. It would be expected that the accuracy of the meter would depend upon the maintaining of the sharpness of the edges, but tests by Miner<sup>16</sup> suggest that in practice the change in discharge coefficient due to this cause will be within 1%.

Miner's test also shows that the Dall tube is more sensitive to upstream conditions than a venturi meter and is, in fact, more comparable with an orifice. This may be related to the fact that the flow in a Dall tube, involving abrupt changes in direction, is similar to that in an orifice and, in fact, the discharge coefficient of the Dall tube is comparable with that of an orifice.

### Flow straighteners

For accurate measurement of fluid

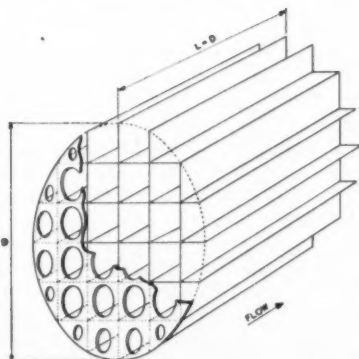


Fig. 1. The graded resistance flow straightener

flow by means of uncalibrated meters the approach flow must be similar to that with which the standard was calibrated. Thus the ideal setting for a flow meter is in a long, straight pipe with adequate upstream settling length. It is often not possible to comply with such requirements and the errors that can then arise have been dealt with above. In an attempt to eliminate such errors, particularly with orifice plates, work at B.H.R.A.<sup>17</sup> has been directed towards developing a flow straightener, i.e. a device which causes the meter to behave as though it were preceded by a long length of straight pipe.

The use of flow straighteners is mentioned only briefly in the standard codes on flow measurement,<sup>2, 4, 18, 19</sup> but recently the problem has received some attention by others.<sup>20, 21, 22</sup> Experimental results suggest that a simple and complete solution to the problem of flow straighteners is not likely to be found, since the correct velocity distribution is not the only factor affecting the orifice discharge coefficient.

A simple uniform resistance, sufficiently powerful to eliminate upstream disturbances, would not be an effective straightener, as the velocity distribution emerging from it would be essentially uniform and would cause a reduction of about 3% in the orifice discharge coefficient with  $m = 0.53$

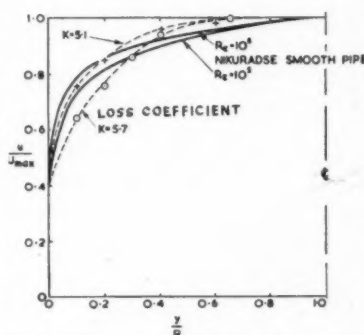


Fig. 2. Velocity distributions behind the graded resistance flow straighteners

and only two to three pipe diameters settling length. The uniform resistance is not very effective against swirl or asymmetrical velocity distributions. The experiments also indicated that a honeycomb removes swirl but may prolong the effects of axial velocity disturbances.

It follows that an effective flow straightener must be of high enough resistance to eliminate upstream disturbances, be graded in resistance so

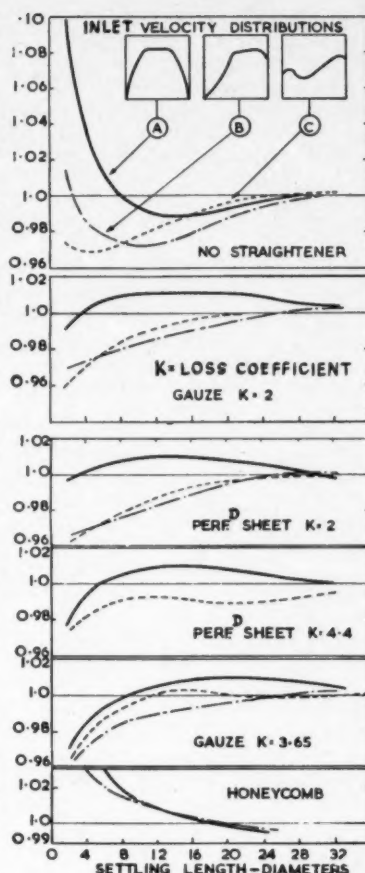


Fig. 3. Performance of various forms of flow smoothing element

Orifice area ratio  $m = 0.53$

D and D/2 taps

Ordinate is the ratio:

$$\frac{\text{Discharge coefficient with disturbance}}{\text{Discharge coefficient with straight pipe}} = \frac{C_d}{C_{d0}}$$

as to produce the correct velocity distribution downstream of it, and be combined with a honeycomb so as to be effective against both swirl and axial disturbances. Such a straightener has been developed and shown to be reasonably effective. Its general appearance is shown in Fig. 1 and more information on its design and performance is given.<sup>17</sup>

Fig. 2 shows the success of the graded-resistance straightener in producing a velocity distribution comparable with that in a smooth pipe at a reasonable working Reynolds number. Fig. 3 illustrates the extent of the error associated with a change in velocity distribution, and the comparative effectiveness of simple gauzes and honeycombs. The superiority of the graded-resistance flow straightener can



be seen in Fig. 4, which shows small errors for both distorted velocity distribution and swirl.

The main objections which have been raised to the use of flow straighteners is the uncertainty of their effects and the high pressure loss associated with them, compared with the very small loss in a sufficient length of straight pipe. But where it is impossible to have sufficient straight pipe upstream of the orifice, it is necessary either to calibrate the orifice and pipe system or to develop and use a flow straightener which will eliminate the errors in discharge coefficient irrespective of the type of flow disturbance involved; and some success in this direction is claimed.

One way of reducing the effects of flow disturbances on the discharge coefficient of orifice plates has been to make the orifice area ratio small. This suffers from two main disadvantages. Firstly, while the errors due to axial velocity disturbances are reduced by decreasing the orifice area ratio, errors due to swirl may even be increased. Secondly, the pressure loss associated with the orifice increases rapidly as the area ratio decreases (Fig. 5).

Although the flow straightener developed has a loss of five to six pipe velocity heads, the combined loss of the straightener and large-area-ratio orifice can be made much less than that of a single small-area-ratio orifice. This is illustrated by the following example.

If, after a right-angled bend, only 10 diameters of straight pipe are available, then according to B.S. 1042<sup>4</sup> the area ratio of an orifice for satisfactory measurements must be less than 0.3. Fig. 5 shows that this will entail a loss of about 20 velocity heads. If, on the other hand, the B.H.R.A. flow straightener is used in combination with an orifice having  $m = 0.53$ , Fig. 4 shows that acceptable accuracy will be obtained within the available 10 diameters. The combined loss will be 5.7 velocity heads due to the straightener and about four velocity heads due to the orifice, i.e. a reduction of 55% in the overall loss.

## Conclusions

This survey has shown that, for accurate (less than  $\pm 1\%$ ) flow measurement, even adherence to the nominal code requirements will not necessarily guarantee reliability. The continuous developments in this field should, however, help to remove the remaining sources of doubt.

On the other hand, it is also true that for many applications where

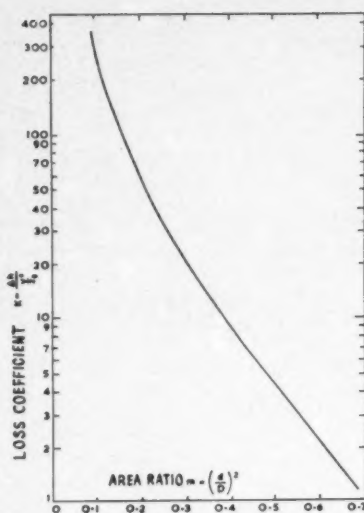


Fig. 4. Performance of graded resistance flow straighteners  
Orifice  $m = 0.53$   
Loss coefficient  $K = 5.7$

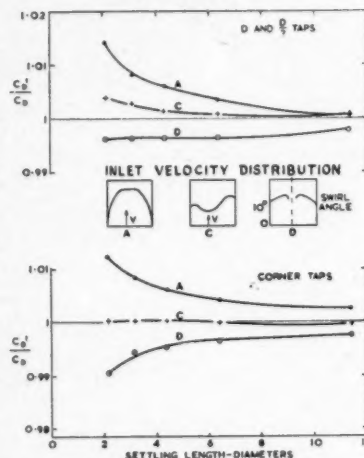


Fig. 5. Loss coefficients for orifices

accuracies of the order of 2% are quite satisfactory, appreciable relaxation of the code recommendations are possible without impairing meter performance. While not advocating carelessness in meter design and installation, it is possible that the information summarised in this note may enable the use of an orifice or venturi in conditions which would, from code recommendations, have appeared unsuitable. The graded resistance flow straightener offers a more rational approach to the problem in ensuring that, irrespective of upstream conditions, the flow approaching the measuring device will correspond to 'ideal' conditions of long, straight pipe. The work has demonstrated that this can be achieved without

unduly increasing the head loss of the measuring system.

## Acknowledgments

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## Polyethylene plant in Japan

A proposal has been placed before the Japanese government by Asahi-Dow Ltd., an associated company of the Dow Chemical Co., for the construction of a polyethylene plant at Kawasaki.

According to the proposal, the new plant would use the high-pressure polyethylene process developed by A.G. fur Olefinpolymerisation (Agfo process).

Asahi-Dow also manufactures styrene, polystyrene and Saran plastics.

# Control of the Flow of Fluids

By K. L. Butcher,\* B.Sc., F.R.I.C., M.I.Chem.E.

*In this article on fundamental aspects of fluid flow and control, the different methods of motivation of fluids by reciprocating, centrifugal, axial flow and propeller pumps are reviewed. Various mechanisms required to control both flow and to apply corrective action are described. By treating factors affecting the stability of automatic flow control by methods analogous to those used in electrical engineering, interesting quantitative comparisons are made. Finally 'hunting' and its effect on the control system is discussed.*

FLUIDS for process work in which they undergo some chemical or physical change, or are instrumental in bringing about such changes in other materials, are usually conducted to the site of the change by pipes or ducts. During the movement of the fluid from storage to plant some degradation of energy takes place on account of irreversible changes such as skin friction, turbulence, throttling, etc. Therefore in the case of a fluid which preserves its chemical identity up to the point of entering the plant zone, there is often an injection of mechanical energy and, in any case, an adjustment of the balance between the content of the different forms of energy, viz. 'positional', 'kinetic' and 'internal' energy. Changes in the latter are taken as being due to the direct addition or subtraction of heat, together with that of mechanical work represented by

$$-\int_v^v p.dV$$

In practice the mechanical effort of a machine acting on a fluid produces both heat and 'pressure energy', both of which add to the internal energy  $U$  of the fluid.

The changes can be summarised by the type of energy equation due to Bernoulli as follows. Using  $Z$  to denote positional energy,  $K$  for kinetic energy,  $U$  for internal energy ( $dU = q - pdV$ ), per unit weight of fluid, and subscripts

$s$  = in storage vessel,

$i$  = inlet to compressing mechanism,

$d$  = discharge from compressing mechanism and

$pr$  = at the process plant.

$$Z_s + K_s + U_s = Z_i + K_i + U_i$$

$$Z_i + K_i + U_i + W_s =$$

$$Z_d + K_d + U_d + Q$$

where  $W_s$  is the energy put into the fluid by the pump or compressor and  $Q$  is the heat removed by cooling

jackets, etc. It is useful to realise for liquids that, where the pump inlet and discharge connections are of the same diameter and at the same level, the 'shaft' energy is absorbed as 'pressure' energy and heat. For gases, this conclusion is reached if the product 'cross-sectional area  $\times$  gas density' is the same for inlet and outlet cross-sections. The latter is due to friction if an adiabatic operation ( $Q = 0$ ) is performed by the shaft mechanism. In isothermal operation, both frictional heat and the heat equivalent of the compressional work done is removed by a cooling system.

Finally, in the absence of any further mechanical or heat energy input or abstraction between the discharge of the motivating unit and the process plant, one can write

$$Z_d + K_d + U_d = Z_{pr} + K_{pr} + U_{pr}$$

Now, since  $W_s$  is the shaft energy input/unit weight of fluid, we see that if  $\varphi$  is the efficiency of driving mechanism of the compression system,  $\frac{W_s}{\varphi}$  is the energy to be supplied to driving mechanism/unit weight of material handled. Consequently, if  $P$  is the input power of the mechanism (e.g. the horsepower of an electric motor) the weight/unit time that may be transferred through the motivating mechanism is

$$\frac{P}{W_s/\varphi} \quad \text{or} \quad \frac{P\varphi}{W_s}$$

(in suitable units).

## Controlling power input

Thus it would seem that the logical way to control the rate of flow of the fluid would be by controlling the power input to the motivating mechanism. In some cases this is quite feasible, more particularly with 'positive displacement' means of pumping, such as the reciprocating piston and the positive rotary types.

The means of achieving this kind of regulation are as follows:

- (1) Constant-speed drives with variable-stroke 'pumps'.
- (2) Constant-'stroke' pumps with variable-speed drives.

In either case it may be advisable to have an independent means of measuring the flow rate and to utilise the measurement so obtained to actuate

- (1) The stroke variation mechanism or
- (2) The speed variation mechanism.

On the other hand, if the flow rate is to be determined by a human judgment as to what the desired value is to be, then use can be made of calibration charts:

- (1) At constant speed, relating 'stroke' length to volumetric rate of output.
- (2) At constant 'stroke' length, relating speed of drive to volumetric rate of output.

Either of the adjustments can then be made by hand and are normally not likely to change further without the intervention of the operator. Even so, a separate means of indicating the magnitude of the flow rate is desirable. In the case of gases the measurement of the weight rate of flow is difficult unless the density of the gas is reasonably constant.

Despite the economic use of power implicit in the above methods of operation, it is not widely used in the chemical and allied industries, and presumably the cost of this type of motivation plus the cost of building in the necessary adjustments to stroke or speed, militate against their wide application. The simplest application of this kind would appear to be the regulation of the steam supply to the drive side of a multi-cylinder reciprocating pump from which the discharge pressure can be smoothed sufficiently to render metering and control by orifice meter a practical proposition. This kind of system needs more consideration than it receives.

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A commonly used device with positive displacement pumps of fixed speed and stroke is that of the by-pass valve to divert from the delivery back into the pump suction the fraction of the gross pump displacement that is not required for process fluid. This is patently wasteful of energy and wears out the pump unnecessarily. It is perhaps due to the great preference for the constant-speed electric drives and the expense of speed-varying mechanisms that methods of regulation of fluid flow which deliberately degrade energy are installed.

### Non-positive displacement

The attractions of systems of a non-positive displacement type of fluid motivating mechanism are low capital cost and ease and flexibility of control of throughput. In many cases these outweigh the savings of energy that may be made with the first types. In their manufacture there would appear to be fewer close tolerances to work to—and in their operation there are not the difficulties of rapidly reciprocating valve mechanisms to overcome. These motivating mechanisms may be centrifugal, mixed flow, axial flow, or propeller types of pump or fan. Their suitability to a given duty depends on the specific speed  $N_s$  concerned, where  $N_s = N\sqrt{Q}/Z^{\frac{1}{2}}$ , where  $N$  = pump shaft speed,  $Q$  = discharge rate at the design point (gal./min.) and  $Z$  = total head, in feet, of flowing fluid at the design point.

According to Addison ('Pump Users' Handbook', p. 65) the following classification is useful for single-stage pumps:

Type of pump	$N_s$
Centrifugal .. ..	$\leq 5,000$
Screw or mixed flow .. ..	4,000 to 8,000
Axial flow .. ..	6,000 to 12,500

The problem of controlling the flow rate at a desirable value is now shifted to the throttling action of an automatically controlled valve, actuated by a measurement of the flow, located as a rule on the discharge side of the pump (liquids). The flow measurement is made between this valve and the pump.

The effect of this arrangement is to control the value of  $P_Q/W_s$  by altering both  $\phi$  and  $P$ . This is made clear by studying the graph of (a) total head, (b) power input and (c) efficiency, as functions of volumetric rate of discharge for a constant-speed centrifugal pump.

By suitable choice of pump for a specific range of duties, the fraction

of the total head 'lost' by throttling control may be minimised and, of course, the problem of control itself is made easier. There is obviously little point in raising the gauge pressure of a fluid to a high value merely to throttle it down to a low value by a controller.

Problems of a somewhat different kind arise when a given type of fluid is energised on a large scale, and distributed in this state to a number of different processes. Services such as water, steam, compressed air, fuels, refrigerants and solvents are examples of this type.

Great care should be exercised in deciding in the first place the optimum energy level (or levels) at which the service fluid is to be made available. Errors of judgment at this stage are most costly in connection with steam. Secondly, careful consideration must be given to the distribution system so that optimum economic pipe sizes are selected for each stage of the distribution network in accordance with anticipated process demands. (See chapters 1, 2 and 3 of Volume 5, 'Chemical Engineering Practice', Cremer and Davies.)

Finally, the type of regulation of the offtake from the central service 'main' to each process plant needs specifying. It must be accepted that fluctuations in conditions in the 'ring main' are difficult to avoid when a number of plants are served by one system, when each plant may have a range of demands to meet. The range of these fluctuations should be estimated in order to specify the duty of the regulating mechanisms governing the offtake to individual plants.

### Steam mains

Perhaps the most difficult situation arises in steam mains, where temperature and pressure may both vary, with consequent effects upon the density. Fortunately, in well-insulated systems the enthalpy/unit weight of fluid may be reasonably constant. In such a case the first step in the offtake procedure might well be to provide an automatic pressure regulator whose action is to attempt to maintain a fairly steady pressure downstream to itself. This may then be followed by an automatic flow controlling mechanism which is set either by hand or by a servo-mechanism, governed by a property value of a fluid in the process plant. This system may savour of 'belt and braces' philosophy, but the outlay may be quickly repaid by stable operation of the process itself. The method just described

is, of course, generally applicable to gases subject to substantial fluctuations ( $\pm 10\%$ ) in density.

The distribution of constant flows of liquids to auxiliary processes is a simpler matter on account of the much smaller fluctuations in density that are normally encountered, especially if wide temperature changes ( $\pm 50^\circ\text{C}.$ ) are absent. Then one can dispense with the pressure regulator mentioned above and use automatic flow control alone, to take care of fluctuations in both the supply mains pressure or in the process plant side of the control valve. Specification of the best type of flow regulator, in relation to the process to be served, becomes more complicated with the increase in the time elapsing between the sudden change of flow rate of fluid to the process and the ultimate appearance of a measurable effect in the outflow of products from the process, due to this change of flow rate.

### Steam heating of oil flow

A case in point may be the steam heating of a flow of oil in a tubular heat exchanger. Suppose the oil flow rate is kept constant by one mechanism and the steam supply flow rate is kept independently constant by mechanisms already mentioned. When the equipment is first 'put on stream' there will be a period during which the outlet temperature of the oil is rising— asymptotically to a fixed value. Then a steady state is reached and the temperature rise of the oil can be related to the ratio of the flow rates of steam to oil (and, of course, to the heating surface area and film resistances, etc.). Suppose that after this state has been established it becomes desirable to halve the rise in temperature of the oil, while maintaining its original rate of flow. It would seem logical to take steps to halve the rate of steam flow by resetting the automatic controller on the steam side and wait for events to take a course which ultimately should result in the desired effect being achieved. Time taken to achieve the new steady state must be dependent upon the heat capacity of the heat exchanger, tubes and the residence time of the oil in the tubes, besides the resistances to heat flow. The question arises as to whether it would not be possible to achieve the desired effect more quickly by shutting off the steam altogether for a certain time and then bringing its flow up to half the value previously required.

Finally, one could try to obviate the necessity of having to decide what the new steam flow setting should be,



by causing the temperature of the outlet oil to be instrumental in setting the steam flow controller. The temperature measurement could certainly be made to actuate pilot mechanisms each time the temperature shifted from a predetermined value by more than a certain fraction of a degree. Furthermore, the predetermined value of temperature would be subject to manual adjustment.

The question arises of what mechanisms are needed in the temperature measuring and controlling system to actuate the steam flow rate controller in such a way as to minimise the time necessary for the change from one steady-state outlet temperature to another.

These problems are partially solved by the use of mechanisms whose corrective actions vary in magnitude, in a predeterminable manner, according to the rate of change of the temperature, according to the magnitude of the difference between the temperature at a given moment and the desired temperature and, finally, according to the product of the error's magnitude and the time that has elapsed from the initiation of the change.

Thus for the above type of problem one would recommend a temperature controller equipped with so-called 'derivative', 'proportional' and 'integral' actions, so that a speedy response could be obtained and at the same time close correspondence of the actual outlet temperature to the desired value. This system of control also enables one to deal with the tendency for stable oscillations to be established. However, it must be pointed out that, in most instances of direct flow control, the refinements of derivative and integral action are unnecessary. They were introduced in the above example as a means of setting a flow controller because of the heat flow characteristics of the system.

The final arbiter of the flow magnitude can conveniently be a 'proportional' type of controller, and considerable economy in outlay on this type of equipment can be made by utilising self-acting flow control valves having rapid responses and high sensitivity. These may be 'set' to control at various desired values by means of servo mechanisms, which are themselves actuated by other variables—for instance, by temperature variations, as already mentioned.

Because the flow measurement and corrective action are carried out at almost the same point, there is a minimum of delay between the development of an error in the flow

magnitude and the initiation of corrective movement of the control valve.

### Methods of measuring flow

The measurement of the rate of flow of fluids is commonly, but by no means universally, based on the pressure drop across an orifice plate, nozzle or venturi tube, installed in accordance with well-standardised practice (B.S. 1042: 1943, and amendments). The general principle of this method is that, where flow is made to change its velocity by a constriction, this change takes place at the expense of the other forms of energy and results in the creation of a difference in gauge pressure between points where the level is the same but the velocity is different. The change in gauge pressure usually exceeds that accounted for by the change in velocity, and this is due to frictional heat being generated. A relationship exists between the change in gauge pressure, the volumetric rate of flow, the density of the fluid and the geometry of the pipes and constriction.

The methods of measurement prescribed are only accurate for calculating flow rates for homogeneous (*i.e.* usually single-phase) fluids. This does not mean that useful indications of the relative magnitude of flow cannot be obtained by other devices and, indeed, much work is done by means of the positioning of a weight supported by the drag of the fluid flowing vertically in a tapered tube. Neither does it mean that useful indications cannot be obtained when a fluid of composition that does not vary with time, but otherwise not sufficiently homogeneous to accord with the 'standard', cannot be obtained with orifices. Special calibration may be all that is necessary under non-standard conditions, and this means that the refinements of tolerances laid down in the standards may be relaxed, since independent calibration is to be performed.

Fluids which are conductors of electricity may have their rates of flow measured by applying a stationary magnetic field to the fluid and measuring the e.m.f. resulting from the movement of the fluid conductor in the magnetic field. Other effects such as the Doppler effect might be used. By comparing the frequency of a vibration impressed on the fluid with that detected after transmission of the signal by the fluid in motion, an estimate of the velocity of flow is made. A spectrum of frequency increments should be detected, since the velocity of the fluid varies with the radial

distance from the wall of the pipe.

Measurement of any kind is greatly facilitated by periods of steady operation. If the mean value of the flow is steady but its instantaneous magnitude varies with time, then the question of measuring the true average of the rate of flow has to be looked into. A knowledge of the function of time which describes the flow rate, analogous to the expressions for current (in electrical work involving a.c. or pulsating d.c.) is helpful in deciding whether damping of the oscillations, both by 'capacities' placed in the main line and by restrictions in the orifice tapping connections where this method is used, is sufficient. Advice is given in the B.S. 1042: 1943, and revised code CX (INE) 9141, as well as on page 283 of 'Flow Measurement and Control', by W. F. Coxon.

'Phased' multi-cylindrical reciprocating pumps having a pneumatic buffer vessel in the delivery line can be made to give fairly smooth flows. Self-acting flow controllers also exert a stabilising influence on such systems.

### Stability of automatic control

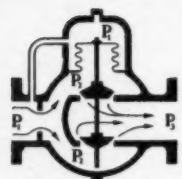
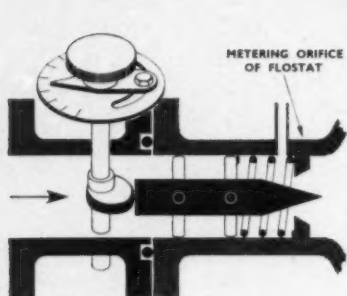
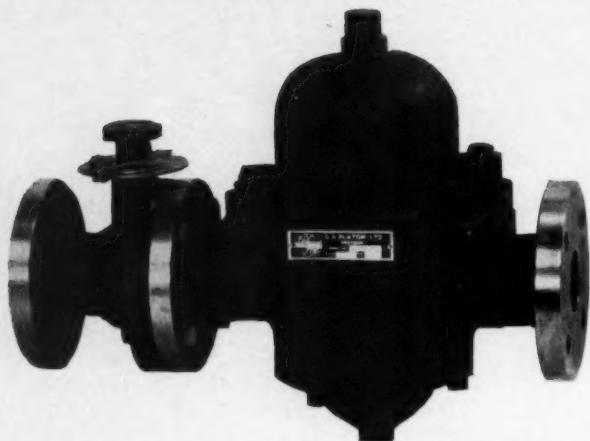
The factors affecting the stability of automatic flow control embrace those affecting flow measurement and can be dealt with in a quantitative way, in simple cases, by methods analogous to those of value in electrical engineering work dealing with fluctuating potentials and currents in systems composed of any or all of the types of component 'resistance', 'inductance' and 'capacitance'. In general one needs interaction (feed back) between at least two possible oscillating systems (or 'capacities') and a continuous supply and dissipation of energy, to reach a state of 'steady hunting'. Furthermore, the two systems need to be in sympathy, *i.e.* of the same 'natural' frequency.

The musical analogue is seen in such instruments as the flute. The length of tube free from openings defines the frequency (or wavelength) of the vibrations that may take place therein. The jet of air emitted by the player into the embouchure produces a regular succession of eddies or pulsations in pressure and velocity, of which the frequency is a function of the velocity. When the player has (almost subconsciously) adjusted the velocity to a certain value, peculiar to the uninterrupted length of tube selected by his fingers, the musical sound is emitted, resonance being established. This example has been given because it involves fluid flow and eddy trails which may also arise

# FLOSTAT DEVELOPMENT

## TYPE "V"

## TYPE "B"



The balanced double-beat poppet valve of the Standard Flostat ensures quick and accurate control.

The Type "V" Flostat calibrated automatic flow controller consists of a Standard Flostat fitted with a setting adjustment device.

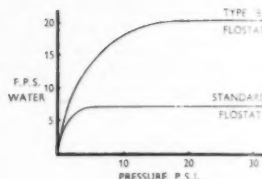
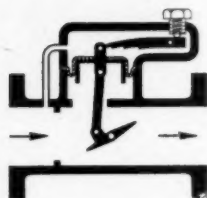
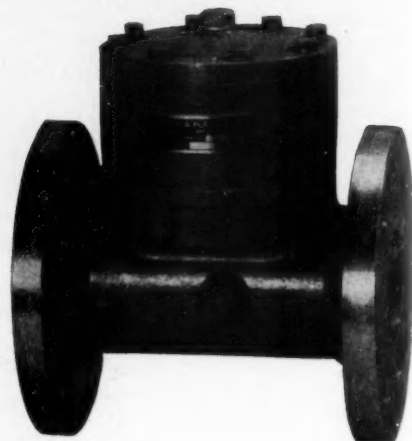
The Flostat applies the pressure differential at a built-in metering orifice to a pressure responsive element directly connected to the control valve. Variations in upstream and downstream pressure tending to alter the flow rate through the orifice result in very rapid readjustments of the valve opening so that the flow rate is kept constant. No outside power supply is required, and the resulting low cost makes automatic flow control available for all processes. The Calibrated Setting Adjuster of the Type "V" Flostat provides the means of altering the area of the metering orifice and consequently the controlled flow rate (up to a maximum range of 10:1). Flostats Type "V" are made for pipe sizes 1", 1½", 4". Prices from £58. For use with Burners, Chemical Plant Units (Still, Evaporators, etc.) and Chemical Processes of all kinds. The Type "V" Flostat enables an accurately controlled flow of gas to a vessel to be adjusted to suit different process requirements. It is much used for fuel oil control because its high response speed minimises overshoot at start-up. It produces accurate control over the wide range of supply and back pressure variations likely to be encountered in emergency conditions which would cause difficulties with other types of automatic valves.

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The Type "B" Flostat self-acting flow governor is intended for protective duties. The butterfly valve limits maximum flow but offers least resistance to normal flow.

Flostats Type "B," either Factory Calibrated or adjustable on site, are made for pipe sizes 2½", 3", 4", 6", and the range is being extended. Prices are from £35. Where visual indication of flow rate is required a Gapmeter can be used in a by-pass line round the metering orifice and the Flo-scan Alarm Switch can be fitted to give a remote signal of low or high flow rate.

For use in safeguarding metering equipment and plant from surges and preventing build-up of static charge.

### The Flostat MINOR

Here is a new self-acting flow controller for very small flows.

It is available either Factory Calibrated or fitted with a Setting Adjuster (best used in series with a Gapmeter). Flow Range: 0.1-50 c.f.h. Air 1-20 g.p.h. Water. Price Range: £8-£15.

Used for sampling (for analysis), purging, cooling or wherever a steady flow is required; e.g. with Trace Additives, Make-up Concentrates, Feeds to Filters, etc.



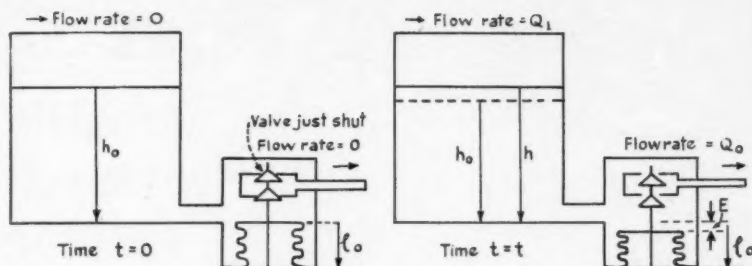


Fig. 1

at obstacles such as valves in plant work. How and why these trails originate is a complex problem dealt with in Lamb's 'Hydrodynamics', pp. 220-229. It is not difficult to imagine that, if the components of the valve system have a 'natural' vibration frequency depending on the spring loading and inertia of the valve, sustained fluctuations in the flow might be produced about certain mean rates of flow in the absence of suitable damping for suppressing them.

### 'Hunting'

Such fluctuations are known as 'hunting' and may result in the magnitude of the error in the controller variable changing sinusoidally with time. Since the external act of creating the error and the primary resultant corrective act are always 'in opposition', the latter can be thought of as 'lagging' 180° behind the former in an 'action circle' in which actions are always directed outwards along a radius. If other parts of the system (capacity) and the control react in such a way as to add, say, 90° each to the lag of 180°, then stable oscillations may be expected. This aspect can only be fully appreciated by setting up, say, the 'force' equations for the central system on the one hand and the simultaneous equations expressing the state of the plant fluid on the other, and then solving them. These, in a simple case, take the form of:

$$\Delta \text{Inertia force} = \Delta \text{pressure force} \\ - \Delta \text{spring force} + \Delta \text{damping force}$$

on a controller where the distances and their derivatives with respect to time may be, at one and the same time, a measure of the error of the variable being controlled, and of the displacement of the controller mechanism (e.g. valve head). The differences,  $\Delta$ , all refer to changes during the same time interval ( $t - 0$ ).

The 'plant' relationships might be as follows. Supposing one had suddenly altered the flow rate from a steady value 0 to a new steady value  $Q_1$ , and the function of the controller was to

maintain a level at a fixed position ( $h$ ) in a tank, then  $Q_1 - Q_0 = A_t dh/dt$ , where  $Q_0$  was the instantaneous rate of outflow.

The following equations describe the situation at time  $t$  in Fig. 1 where  $A_b$  = area of bellows (normal to valve stem)

$A_t$  = area of tank cross-section (horizontal)

$N$  = damping constant, proportional to a linear dimension of moving parts and to viscosity of fluid.

$A_0, A_1, A_2$  are numbers for a particular system, such that the dimensions of each term in the equation are 'length/(time)<sup>3</sup>'.

$$Q_1 - Q_0 = A_t dh/dt \dots \dots (1) \\ \text{(conservation of matter, neglecting bellows displacement)}$$

$$Q_0 = K(E)(h)^{1/2} \dots \dots (2) \\ \text{(orifice type of equation for valve throttling)}$$

If  $M$  = effective mass of moving parts of valve,  $B$  = spring rating of bellows in these circumstances.

$$M \left( \frac{d^2 E}{dt^2} - 0 \right) = \\ (h - h_0)A_b - B(E - 0) - N \left( \frac{dE}{dt} - 0 \right) \dots \dots (3)$$

where  $E$  and  $h$  are measured downwards from the valve seat and from the liquid surface respectively. This assumes that there is in the beginning imperfect correspondence between the rise in level ( $h - h_0$ ) of the tank and the depression  $E$  of the bellows. Otherwise the centre pair of terms would cancel one another (in many instances they probably do cancel for practical purposes, after a second or two).

Putting (2) into (1) and then using the result in  $d(3)/dt$  we get

$$M \frac{d^3 E}{dt^3} = \\ \frac{A_b}{A_t} (Q_1 - E\sqrt{h}) - B \frac{dE}{dt} - N \frac{d^2 E}{dt^2} \dots \dots (4)$$

It might be assumed as one hypothesis that eventually there is a correspondence between  $(h - h_0)$  and  $BE$ , or

$$(h - h_0)A_b = BE(1 - e^{-kt}) \dots \dots (5)$$

Thus in (4) instead of the

$$\frac{A_b}{A_t} (Q_1 - E\sqrt{h})$$

used for  $A_b dh/dt$ , one notes that from (5)

$$\frac{dh}{dt} = \frac{B}{A_b} \left( \frac{dE}{dt} E k e^{-kt} - e^{-kt} \frac{dE}{dt} \right)$$

So that we have

$$M \left( \frac{d^3 E}{dt^3} \right) = k B e^{-kt} E - B e^{-kt} \frac{dE}{dt} \\ - N \frac{d^2 E}{dt^2} \dots \dots (6)$$

This, after a long time, must become  $M(d^3 E/dt^3) = -N(d^2 E/dt^2)$ . However, this tacitly ignores the 'plant' equations and it is necessary to take into account (4) and (5) together, to embrace the whole system. By using (5) we have

$$\sqrt{h} = \left[ \frac{BE}{A_b} (1 - e^{-kt}) + h_0 \right]^{1/2}$$

so (4) becomes

$$M \frac{d^3 E}{dt^3} = \frac{A_b}{A_t} (Q_1 - \\ \left( \frac{A_b}{A_t} \right) E \left[ \frac{B}{A_b} E (1 - e^{-kt}) E + h_0 \right]^{1/2} \\ - B \frac{dE}{dt} - N \frac{d^2 E}{dt^2} \dots \dots (7)$$

or rearranging

$$\frac{d^3 E}{dt^3} + \frac{N}{M} \frac{d^2 E}{dt^2} + \frac{B}{M} \frac{dE}{dt} + \\ \left( \frac{A_b}{M A_t} \right) \left[ \frac{B}{A_b} (1 - e^{-kt}) E + h_0 \right]^{1/2} E - \\ \frac{A_b}{M A_t} Q_1 = 0 \dots \dots (7a)$$

Here the fourth term makes the solution (for short times) awkward as compared with the hypothetical equation

$$\frac{d^3 E}{dt^3} + A_2 \frac{d^2 E}{dt^2} + A_1 \frac{dE}{dt} + A_0 E \\ = 0 \dots \dots (8)$$

in which it is known that if  $A_2 \times A_1 = A_0$ , then steady hunting occurs (page 137, 'Automatic Control Engineering', by Ed. Sinclair Smith).

As a final note, it is in practice difficult to find conditions under which the set-up described would hunt, when moving parts are free from adventitious restraints.



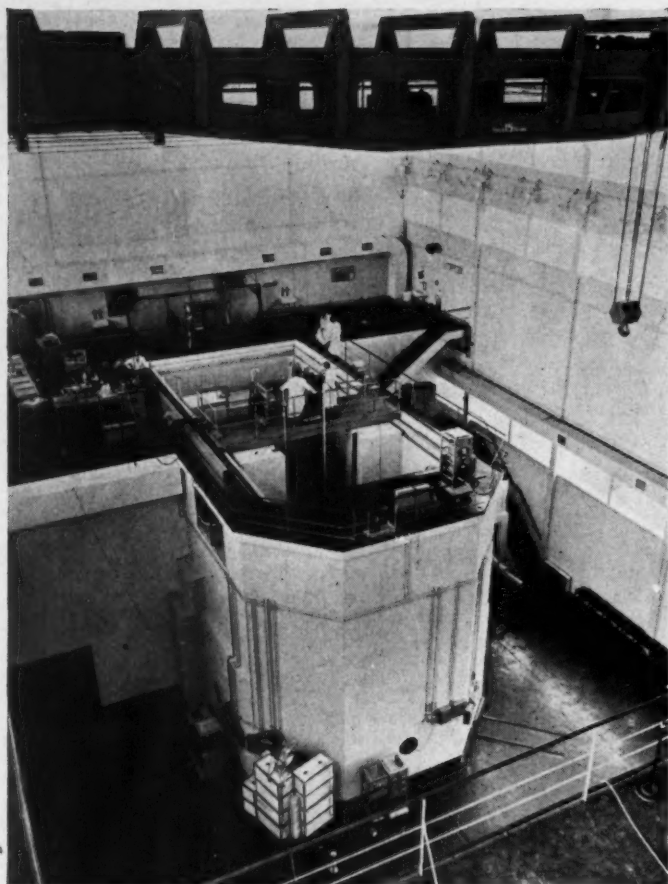


Fig. 1. MELUSINE pool-type reactor

# MELUSINE

## A versatile research reactor

By B. Fabre\* and P. Fradin†

*The MELUSINE light-water-moderated, pool-type research reactor has been in operation at the Centre d'Etudes Nucleaires, Grenoble, France, since 1958. Although the nominal rated output of this reactor is 1 MW, a maximum output of 2 MW has been attained; output is limited by the maximum water temperature which should not exceed 40°C. Problems associated with the design of the reactor cooling circuits are discussed in this article; cooling of the core is achieved by either natural or forced convection. The flexibility and relatively low cost of this reactor are some of the advantages claimed.*

**M**ELUSINE is an 'open-swimming-pool'-type research reactor with a rated output of 1 MW.

The fuel (American-type H.T.R. elements) consists of uranium, enriched with 20%  $U^{235}$ . Moderator, reflector, coolant and biological shielding are provided by the light water of the pool. The peak neutron flux at 1 MW is about  $10^{13}$  thermal n./sq.cm./sec.

### Reactor

The swimming pool itself is a parallelepiped, constructed of prestressed concrete, which is required for protection against radiation. The different inlet and outlet ducts of stainless steel (two coolant intakes, coolant return, purification intakes, purification return, three draining outlets, and channels) were embedded in the concrete during construction.

The internal cladding (water/concrete insulation) consists of glazed sandstone tiles with *Araldite* joints.

The swimming pool has three compartments which can be isolated by an aluminium caisson.

A travelling bridge carries, by means of a vertical aluminium frame, a fuel element carrier lattice. In the two 1-MW working positions the lattice can be locked with all the coolant intake piping. The same bridge also carries all the control instruments and core control equipment, bar control mechanisms and flux detectors. The fuel elements consist of sets of 12 rods, each containing 14.8 g.  $U^{235}$ . The underside of each element is finished in such a way that the element can be fixed in the lattice and the water can pass between the rods and through the supporting lattice.

A bridge and two beams, likewise of the travelling type, serve to carry the specimens submerged in the pool.

Experimental access points are: (a) four radial circular channels of 150 mm. diam. and one tangential channel of rectangular cross-section (100 ×

100 mm.) in the front compartment; (b) one compressed-air pipe carried by the vertical frame of the reactor core bridge; (c) those holes of the core lattice which are not occupied by fuel elements or by the cartridges; and (d) the volume of the swimming pool around the core, which allows for large volumes of irradiation in strong gamma fluxes with non-negligible fluxes of thermal neutrons.

### Structure

The swimming pool is contained in a large, semi-tight hall measuring 34 × 20 × 19 m. In the rear, two shielded rooms (protected by at least 60-cm.-thick concrete) contain the cooling water de-activation tank (capacity 18 cu. m.) and the swimming pool water purification circuits, respectively.

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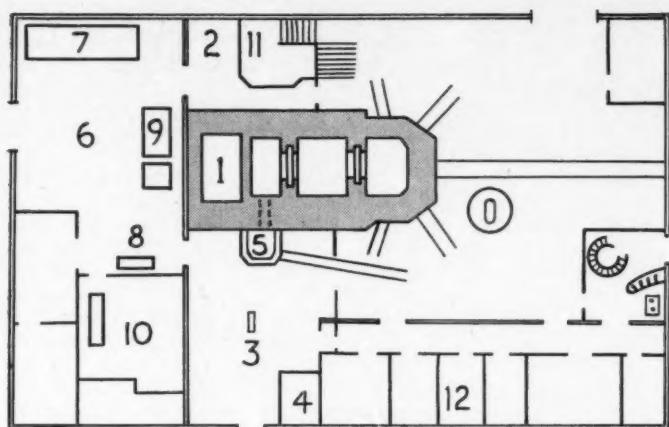


Fig. 2a. Ground floor

1—deactivation bath, 2—water room, 3—work room, 4—pneumatic tube intake, 5—hot cell, 6—machine room, 7—electric switchboard, 8—compressed air, 9—control board, 10—ventilation-heating, 11—plug storeroom, 12—laboratories, offices

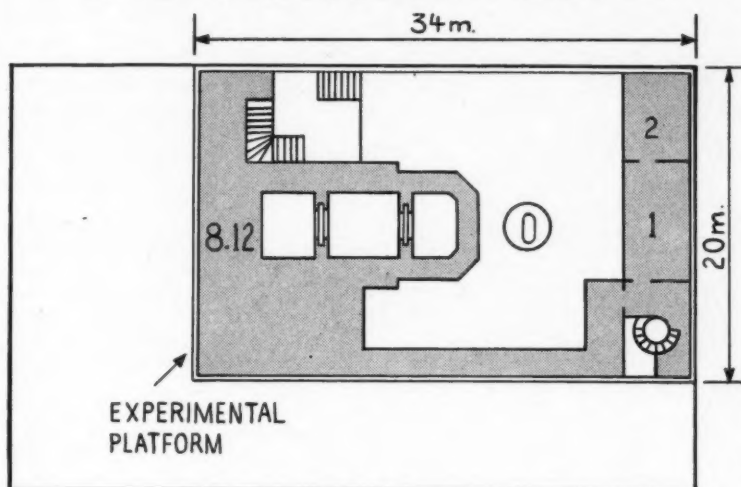


Fig. 2b. 1st floor height 3.5 m. (unshaded area)

1—control room, 2—emergency reactor control circuit

2nd floor (shaded area) height 8.12 m.

1—electronic laboratory, 2—emergency lighting supply

Table 1

Probe	Location	Temperature measured
$S_{13}, S_{23}, S_{33}, S_4$	On a vertical in the front part of the swimming pool	Water in the front compartment
$S_9$	On the vertical frame above the reactor core	Water entering the core
$S_{10}$	In the neck of the cooling funnel	Water leaving the core
$S_{11}$	As $S_9$	Difference in the temperature of the water across the core ( $\Delta t$ )
$S_{12}$	At the inlet of the de-activation tank	
$S_{13}$	Just above the core	Vicinity of the core (high-speed safety device)

Around the hall are arranged (Figs. 2): (a) a water room with the purification circuits for the swimming pool replenishment water and the pumps and heat exchanger of the cooling circuit; (b) a work room with

the terminal of the compressed-air pipe and a hot cell of 10 kc of 1 MeV, communicating through a lock with the rear of the swimming pool; (c) a machine room with the electric control boards, air compressors, the in-

strument and control boards for the water circuits and the circuits for the evacuation of active effluents, heating and ventilation, and a general workshop; (d) a control room where all the equipment required for controlling the reactor is concentrated (movement of the control bars, measurements of power and health variables); (e) two rooms for the independent electric installation of the sector feeding the reactor control circuits and the emergency lighting; and (f) various laboratories and offices.

A special ventilation circuit is used for the hall, the water room and the work room. This circuit allows for recirculation, if desired, of the air in these premises by retaining the active dust particles in high-capacity filters.

### Thermal measurements

Certain monitoring points are connected to the cooling circuits, and measure the flow in the primary and secondary water circuits and the inlet and outlet temperatures of the heat exchanger. To these must be added the temperature readings in Table 1.

All these probe thermocouples are of the platinum resistance type (100 ohm. at 0°C.) The readings of  $S_1$  to  $S_{10}$  are recorded on a 10-channel recording instrument. If a certain pre-set temperature (normally 35°C.) is exceeded on any of these channels the control bars are tripped. Reading instruments  $S_{11}$  and  $S_{12}$  feed a direct value of  $\Delta t$  into a thermal power computer.

Finally, another safety device causes the control bars to be tripped if the flow of water in the primary circuit drops below 150 cu.m./hr. (the normal flow being 200 cu.m./hr.).

### Evaluation of heat output

The conditions to be observed from the outset in the cooling system of the MELUSINE-type reactor are:

(i) To ensure protection of the fuel elements:

(a) When working at continuous rating, the temperature at the sheath of the fuel elements must not be allowed to reach a level dangerous to continuous working.

(b) When working at short-time rating, the temperature at the sheath of the fuel elements must not be allowed to reach a level dangerous even to short-time working (a level which will, of course, be higher than the level dangerous to continuous working).

(c) The elements must not be exposed to a dangerous heat cycle.

- (ii) To ensure smooth operation:
  - (d) Formation of bubbles (escaping gas, boiling, etc.), which affect control and may contaminate the air in the hall, should be avoided.
  - (e) Any tendency of natural convection of water from the pool should be reduced to a minimum in order to limit the surface radiation rate.
  - (f) The mean temperature of the water in the pool should be fairly low in order to reduce the surface evaporation of the pool and the corrosion rate of the materials immersed in the pool.
  - (g) The precision of the ascertainable reactor heat balance should be as high as possible in order to calibrate the indispensable neutron measurements.
- (iii) The primary and secondary cooling circuits should be strictly separated from each other so that the water in the secondary circuit does not become contaminated and can be released into the sewers.

#### Solutions adopted

Condition (iii) has been fulfilled by arranging the circuits in such a way that the pressure in the secondary circuit is always higher than that in the primary circuit. It will be seen later in this article how, in the MELUSINE project, the cooling circuits have been designed with a view to satisfying all the other conditions as well. The results obtained after more than one year of operation have confirmed these expectations.

#### Safe working

Conditions of safe working can be defined by the following upper limits:

- Mean temperature of the swimming pool: 40°C.
- Short-time maximum temperature on the sheath of the fuel elements: 100°C.
- Maximum permanent temperature on the sheath of the fuel elements: 75°C.
- Radiation dose at the surface of the pool: one maximum admissible dose (L.M.A.) (present standard, 7.5 mR/hr.)
- Radiation dose in the non-protected water rooms:  $\frac{1}{10}$  L.M.A.

Because of the relatively low power of the reactor, the problem of heat cycles does not arise as long as the other conditions are satisfied.

#### Conception of the cooling system

The heat formed in the core can be removed by natural convection if the

reactor works at low power. For continuous operation, all this heat is removed through the free water surface. As the temperature of the water is limited to 40°C., the maximum power that can be dissipated at an ambient temperature of 20°C. is 50 kW. At short-time rating, on the other hand, assuming that the temperature of the water is allowed to rise at the rate of 2°C./hr., it is possible to obtain 1,000 kW for a water volume of 400 cu.m. without risk of boiling. In this case, however, nitrogen-16 rapidly displays a prohibitive activity on the surface. For that reason, the working range for natural convection is limited to 100 kW. Power in excess of this value is removed by forced convection.

It is possible to change from forced convection to natural convection, by means of an automatic safety valve, should the pumps fail.

#### Working at continuous rating

The working characteristics for a low-power pile with natural convection have already been mentioned. Above 100 kW and up to the rated power of 1,200 kW, use is made of forced convection cooling by means of a cooling circuit. The water flows from the top downwards across the fuel elements, an arrangement which prevents the flow of contaminated water to the surface of the pool. The throughput is 200 cu.m./hr., corresponding to a water velocity of 0.50 m./sec. between the fuel rods.

Under these conditions, the temperature of the water will rise by 5°C. as it passes through the core when working at 1,200 kW. The core has two alternative working positions for forced convection.

#### Design of cooling circuit

Consider the reactor core in one of its two working positions. The primary cooling circuit consists (following the direction of the flow) essentially of: a suction device with automatic valves installed below the reactor core lattice; a de-activation tank of 18 cu. m. capacity; shut-off valves; three pumps of 100 cu.m./hr. capacity each (including one serving as a stand-by unit); a tubular heat exchanger; and a spray diffuser in the swimming pool. The pipes have a diameter of 150 mm.

Apart from the safety valve, which is made of aluminium A5, the whole installation is made of low-carbon stainless steel 18/8; the flange unions on the upstream side of the de-activation tank are of stainless steel

and those on the downstream side of *Perbunan* rubber. The pump joints are of the mechanical type. The de-activation tank ensures the abatement of short-lived isotopes ( $N^{16}$ ,  $O^{19}$ ) by holding the water for a period of 4 min.

All the plant, except of course the safety valve and the spray diffuser, are outside the swimming pool. The pipes connecting the core with the de-activation tank are embedded in the concrete of the pool. The tank is placed at the back of the pool in a closed room protected by concrete. Pump room and heat exchanger are permanently accessible, as the radioactivity beyond the tank is negligible.

This arrangement of the cooling installation has certain advantages: the active pipes are protected and the inner space of the pool is completely untrammelled; it permits the use of conventional pumps and facilitates maintenance of the pumps, shut-off valves and heat exchanger, as well as the various measurements on the circuits. On the other hand, this arrangement calls for relatively long piping and for very careful sealing. A leak in these pipes may necessitate draining of the pool.

The cooling circuit has been designed so as to obtain economic working of the plant. The bends have large radii. Straight tee pipes have not been used, and are replaced by curved tee pipes. Similarly, the heat exchanger has been designed so as to keep the head losses down to a very low level. In the following section certain details concerning the safety valve, heat exchanger and diffuser are discussed.

#### Safety valve

This novel-type valve (Fig. 4), which was designed and constructed in these laboratories, enables the core to be cooled by forced convection when working at power and also by free convection when the pumps are stopped. It comprises a pyramid-shaped funnel with four faces integrated with the core lattice and the intake piping by means of a sliding rod which can be operated from the service bridge of the core. It is thus possible to work with free convection at any point of the pool.

Two of the faces of the funnel are fixed, whilst the other two are open and can be adjusted by two hinged valves. When the pumps are working, the reduced pressure created below the lattice causes the valves to lie flat against the funnel so that the whole throughput of the pumps passes



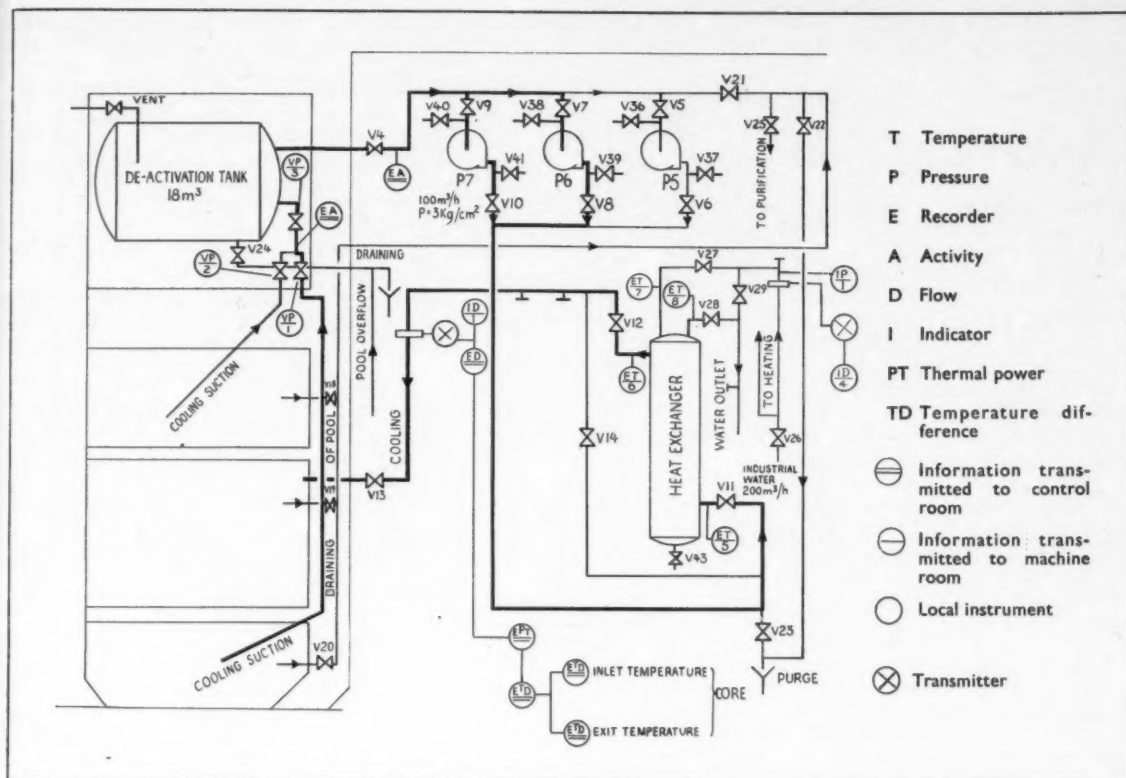


Fig. 3. Cooling system

through the core. If the pumps stop, the valves will open and will allow the water to pass through the core by natural convection.

Each valve is fitted with an adjustable head which enables the restoring

force to be varied. The final flows are set as follows:

	Cu.m./hr.
Closing flow .. ..	100
Reopening flow .. ..	49
Re-closing flow for natural convection .. ..	70

#### Heat exchanger

The tubular heat exchanger, which has fixed tube plates, is made entirely of 18/8 low-carbon steel. The hot fluid flows through the jacket whilst the cooling water circulates in the tubes. This arrangement permits easy cleaning. The technical data are as follows:

**Jacket**  
 Diameter: 400 mm.  
 Number of passes: One  
 Fluid: Exchanged water  
 Inlet temperature: 35°C.  
 Outlet temperature: 30°C.  
 Flow: 200 cu.m./hr.  
 Head loss: 320 g./sq.cm.

**Nest of tubes**  
 Tube diameter: 15/18  
 Triangular mesh spacing: 22 mm.  
 Number of passes: Two  
 Number of tubes per pass: 123  
 Length: 4,800 mm.  
 Fluid: Ordinary water  
 Inlet temperature: 15°C.  
 Outlet temperature: 24°C.  
 Flow: 100 cu.m./hr.

The tubes are secured and welded to the tubular plates.

#### Diffuser

The primary water is restored to the pool by means of a spray diffuser which avoids any water agitation that may impair visibility in the pool. The diffuser is also constructed of stainless steel. Internal baffle plates ensure uniform distribution of the flow towards the outlet orifice where the water velocities are very low. Owing to this arrangement, the surface of the pool is perfectly calm.

#### Working at short-time rating

If the pumps are disconnected, the safety bars of the pile drop, and the safety valves fitted below the core open automatically as soon as the flow becomes less than 49 cu.m./hr.

The sequence of events is as follows, at  $t = 0$ :

The safety bar catch is released with a time lag of 0.3 sec. required for the release of the electro-magnets, and another 0.5 sec. passes before the bars have dropped completely. From that moment ( $t = 0.8$  sec.), the flux becomes very weak but fades out only

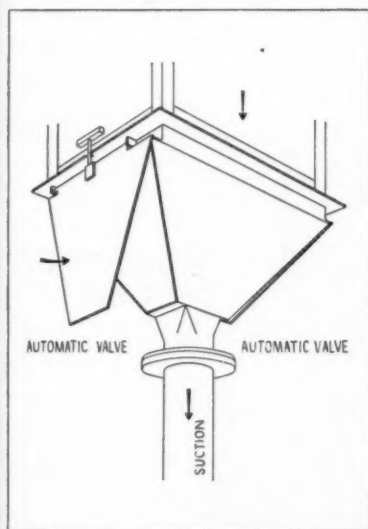


Fig. 4

gradually under the effect of the retarded neutrons and the radio-activity.

The pumps continue to operate but are slowed down as the result of the inertia of the rotating masses and of the water of the cooling circuit. When the flow of forced convection has been reduced sufficiently, the safety valves open:  $t_1 = 2.5$  sec.,  $Q = 49$  cu.m./hr. and  $v = 6.1$  cm./sec.

The flow passing through the core from top to bottom is determined by the throughput of the pumps. Immediately after the opening of the valves, the temperature rise in the water passing through the core results in a thermo-siphon effect acting in the upwards direction which counteracts the existing flow, until the latter is stopped and finally reversed so that a natural convection flow in the upwards direction is set up, passing through the funnel across the valve openings.

The sequence of events from the moment of interruption is as shown in Table 2.

- (b) Uranium combustion, causing a change in the ratio of maximum and mean flux.
- (c) Changes in the levels of the control bars due to the consumption of the core, modifying the form of the neutron flux.

### Results of measurements

Table 3 summarises some of the values observed. They include:

$t_m$  = Mean water temperature in the core compartment.

$t_M$  = Water temperature at the core outlet.

hr. in a core of 25 elements with sinusoidal distribution of the neutron flux.

$t_r$  = Inlet temperature of the (secondary) cooling water.

The non-corrected value of the thermal output, which can often conveniently be compared with the neutron output, is given by the formula:

$$P_{(kW)} = 1.157 \times Q_{(cu.m./h)} \times \Delta t_{(^\circ C.)}$$

where  $\Delta t = t_M - t_m$ .

Without going into details as to the degree of approximation of these output measurements, it is relevant to

Table 3

Date	Neutronic power (kW)	Thermal output (kW)	Configuration of core	$t_m$ (°C.)	$t_M$ (°C.)	$t_g$ (°C.)	$t_r$ (°C.)
20/ 3/59	1,000	900*	No. 2	19.3	23.3	45.5	11.4
10/ 7/59	1,000	967	No. 2	19.7	23.5	48.2	12.3
12/12/59	1,000	1,135	No. 9	22.8	27.3	56.6	12
6/ 2/60	1,000	1,109	No. 9	20.5	24.9	53.5	10.8
2/ 4/60	1,000	1,235	No. 10	21.5	26.4	58.3	9.5
15/ 4/60	1,400	1,488	No. 10	24.2	30.3	68.5	8.9
21/ 4/60	1,600	1,679	No. 10	25.9	32.5	75.5	8.9

\* Precision measurement

Table 2

Time (sec.)	Event	Water velocity (cm./sec.)	Core power (kW)	Maximum temperature of sheath (°C.)
0.0	Pumps disconnected	-50	1,800	97
0.3	Bars released	-40	1,800	
0.8	Bars dropped	-25	340	94
2.5	Valve opened	-6	340	80
4.3	Current reversed	+0	335	81
6	Natural convection	+3.6	330	83
12	Natural convection	+8.3	320	86

A comparison of the temperatures measured and those calculated beforehand requires a fairly precise determination of the output.

### Methods of measuring output

During the early trials of MELU-SINE in 1959, the neutron flux for the virgin core was measured and the results were used for calibrating the output of the neutron measuring chains. In March 1959, a precise thermal balance was compiled during the first 100-hr. run at 1,000 kW. Since then it has not been possible, due to the intensive use of the reactor, to carry out similar measurements with such a precision. The calibration of neutron chains has not been repeated, and occasional thermal balance calculations can only serve to confirm the estimated changes of the thermal output. The principal causes of these changes (due to neutron flux in the centre of the given core) are these:

- (a) Changes in the geometry of the core (Fig. 6 shows those used since March 1959).

$t_g$  = Temperature at the hottest point of the fuel element sheaths, estimated with the aid of the formula

$$t_g = t_o + 7.52 (t_s - t_o)$$

where  $t_o$  and  $t_s$  are the inlet and outlet temperatures of the core; this formula has been established for a flow of 200 cu.m./

point out that the most important variables are the mean and maximum temperatures, and that these are known with sufficient approximation to ensure the safety of the reactor.

As regards  $t_g$ , owing to the ageing of the core and increase in its volume, which reduces the ratio of maximum and mean flux, the estimated values err, *a priori*, on the high side.

It will be seen that, up to 1,600 kW (the maximum working limit), the performance of the pile is satisfactory.

When working at 1 MW, the pumps were accidentally disconnected on several occasions. This reduction in the cooling flow caused tripping of the safety bars, followed by opening of the safety valves at the funnel. The perfect condition of the fuel elements and the absence of bubbles are the only indications available that the original

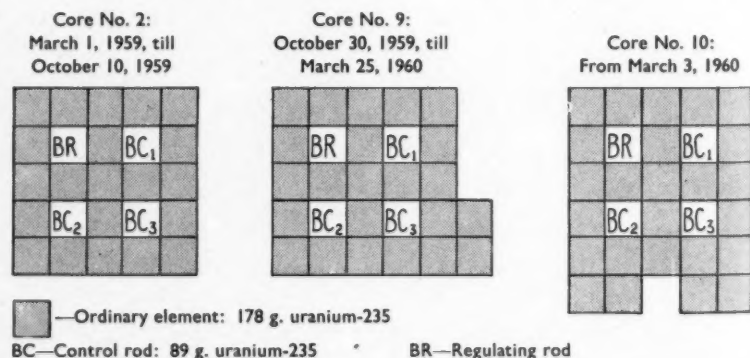


Fig. 6. Core assembly

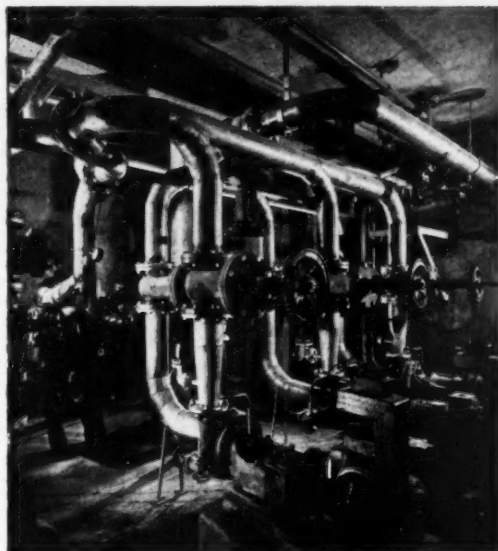


Fig. 5. Pump room

assumptions concerning the automatic transition from forced convection to natural convection were correct.

#### History of MELUSINE reactor

MELUSINE went critical for the first time in July 1958. After physical measurements on the virgin core, the reactor worked at 1,000 kW on March 13, 1959. Since then, it has worked satisfactorily, mostly at its rated power of 1,000 kW, with continuous power runs from Monday afternoon to Saturday evening, i.e. approximately 120 hr./week. By April 15, 1960, the integrated output was 160 MWJ.

The principal applications of the pile are as follows:

*Simple irradiations.* Solid-state physics, biology, behaviour of materials and radioisotopes.

*More complex irradiations (high or low temperature, different atmospheres).* Solid-state physics, reactor technology and radio-chemistry.

*Loops of a more or less complex nature.* Solid-state physics, radio-chemistry, and reactor technology.

*Utilisation of neutron emission.* Neutronic diffraction.

*Teaching instruction.* Practical work as part of the courses in nuclear engineering.

#### Maximum output

As the reactor is working satisfactorily, an attempt to establish the maximum output obtainable without prejudice to safety and without modifying the installation was made.

It was found that, when working with natural convection, the surface of the pool had one dose L.M.A.

(7.5 mR./hr.) for about 200 kW, when the temperature of the water leaving the core by convection was 32°C.

When working with forced convection for the purpose of a short-time trial, gas bubbles from the water at just under 2,000 kW with core No. 2 (25 elements) were encountered. The surface radiation dose was then only one-third of the L.M.A. dose (2.5 mR./hr.), whilst the inlet and outlet temperatures of the water in the core were 18.5 and 27°C, respectively.

Long-time trial runs of approximately 100 hr. have shown the limit of normal working at 1,600 kW, with the following values:

'Neutronic' power: 1,600 kW. Maximum thermal neutron flux less than  $3 \times 10^{13}$  n./sq.cm./sec.

Temperatures: Exchanger:  
Swimming pool: 26°C. 32.5° to 25.5°C.  
Core outlet: 35.5°C. 8.9° to 22.0°C.  
Maximum on fuel element sheaths: 75°C.

Cooling flows: Primary 220 cu.m./hr., secondary 100 cu.m./hr.

Pool surface activity: 7 mR./hr.

No gas escape or abnormal activity of the water after 120 hr.

#### Conclusion

It can be stated that the expectations at the time of designing the MELUSINE project have been fulfilled. Up to approximately 2 MW and peak neutron fluxes of  $2$  to  $3 \times 10^{13}$  n./sq.cm./sec. have been attained. The relatively simple design of an open-pool reactor of the MELUSINE type does not appear to require any complex cooling circuits; it is, on the contrary, the simplicity of these circuits which is one of the advantages of this type of reactor.

In future, investigations will be concerned with some judicious modifications that might expand the output ceiling without excessive costs and without foregoing the two main advantages of a reactor of the MELUSINE type—safety of operation and flexibility in use.

### Linear electron accelerator

The world's most intense precision source of ionising electron-beam radiation—a microwave linear electron accelerator (LINAC) designed to performance specified by the U.S. National Bureau of Standards—will be constructed by High Voltage Engineering Corporation under contract to the Bureau. The cost of the accelerator will be more than \$1.7 million.

The accelerator, essentially a 100-ft.-long straight pipe through which electrons are accelerated on the crest of a travelling microwave, has been designed to produce electron beams with peak energies up to 150 MeV and power outputs of 40 kW or more.

Installation of the accelerator is expected to take place in late 1962. Segments of the machine will have been assembled and tested, prior to

delivery, in a 100-ft. specially designed radiation-proof vault at Walnut Creek, California, the home of Applied Radiation Corporation.

The accelerator will be installed as part of the new laboratories of the National Bureau of Standards to be constructed at Gaithersburg, Md., 20 miles northwest of Washington, D.C. The Gaithersburg facility, which will include laboratories for engineering mechanics, radiation physics and other research, will provide the Bureau with the modern laboratory facilities it needs to meet its research responsibilities.

The high-energy LINAC will be installed below ground-level, making use of the inexpensive radiation shielding of earth. Individual radiation laboratories will be shielded from each other by concrete walls up to 12-ft. thick.



## INDUSTRIAL PUBLICATIONS

**Lead batteries.** The Lead Association's brochure on lead for batteries in the 'Applications of Lead' series has been extensively re-written and brought up to date. Copies are available for those not requiring information of a high technical nature.

**Greases.** A booklet containing an up-to-date list of *Gredag* greases and compounds has been published by Acheson Colloids Ltd. The grades listed are arranged in seven sections: calcium, sodium, lithium (all three soap bases), bentone base, mixed base and special compounds, glassworking lubricants and metalworking lubricants.

**Pipework.** A brochure on industrial pipework issued by the pipework engineering division of Stewarts & Lloyds Ltd. has been compiled to assist engineers and all who are concerned with the design or purchase of pipework. Fully illustrated, it contains information of a general character besides dealing specifically with the services that the division has available.

**Vacuum furnaces.** Two recent publications describe the standard range of vacuum furnaces made by the General Electric Co. Ltd. in association with Vacuum Industrial Applications Ltd. and British Geco Engineering Co. The first is on vacuum induction furnaces suitable for melting and casting metals gas-free, from crucibles ranging in capacity from 1 lb. to 1 ton. The second describes 'cold rotor' types of vacuum resistor furnaces which are suitable for the laboratory or for production.

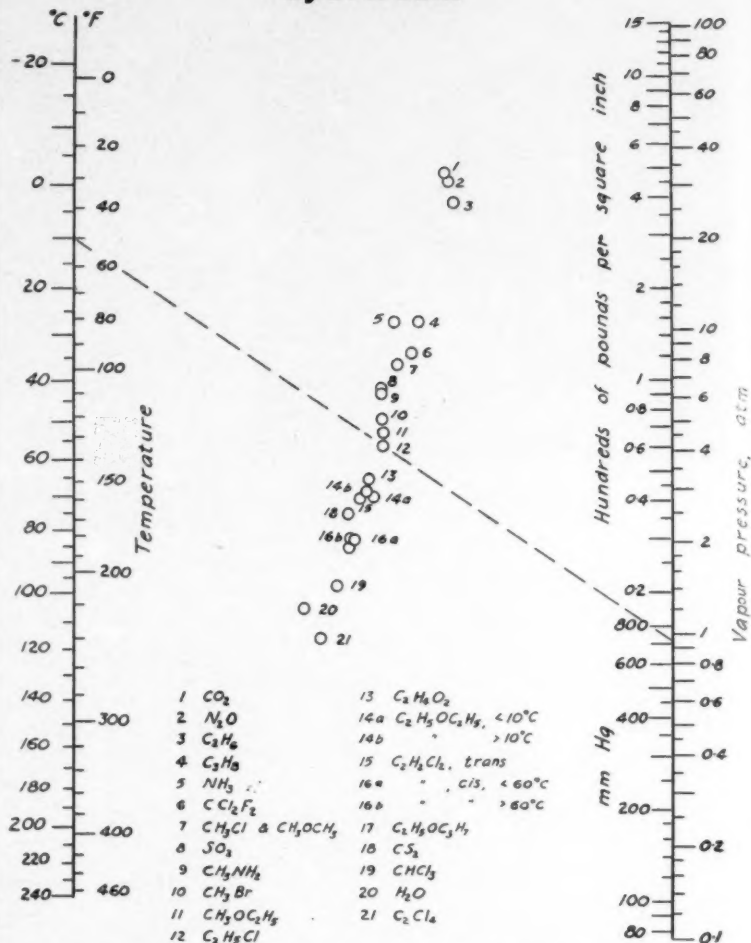
**Packings and jointings.** A catalogue which gives detailed information and guidance on the selection of packings and jointings for individual needs and lists the *Angus* range of packings and jointings has been published by George Angus & Co. Ltd.

**Coolers.** Brief descriptions of the various types of evaporative coolers in current use and numerous illustrations of typical plants supplied in recent years by Visco Engineering Co. Ltd. are given in a recently published brochure. Seven pages of meteorological information and several tables are features of this publication.

**Silicone lubricants** are described in a booklet published by Midland Silicones Ltd. It outlines their pro-

## Vapour Pressures of Refrigerants

By D. S. Davis\*



Vapour pressures of refrigerants can be determined by means of the accompanying line co-ordinate chart. Based on the linearity of the logarithm of pressure with the reciprocal of absolute temperature as reported,<sup>1</sup> the chart was constructed through application of standard methods.<sup>2</sup>

On the nomograph the broken index lines show that the vapour pressure of ethyl chloride (C<sub>2</sub>H<sub>5</sub>Cl) at

10°C. (50°F.) is 0.94 atm. (715 mm. Hg).

### REFERENCES

- <sup>1</sup>J. H. Perry, 'Chemical Engineers' Handbook', 3rd ed., pp. 156 and 1687. McGraw-Hill, New York, 1950.
- <sup>2</sup>D. S. Davis, 'Nomography and Empirical Equations', Chap. 10. Reinhold Publishing Corp., New York, 1955.

\*Professor, Department of Pulp and Paper Technology, University of Alabama.

erties and suggests applications where they can help to cut maintenance, repair and inspection costs, improve performance and generally achieve greater economy in the operation of many types of equipment.

**Conveyor belting.** A booklet recently published by Rubber Improvement Ltd., while dealing specifically with *Green Bond* conveyor belt-

ing, is at the same time a general reference work on conveyor belting.

**Dust collection.** A publication covering—by description, drawings, photographs and capacity tables—the new range of *Tornado-Cyclogal* high-efficiency dust collectors, which are available in seven sizes, with normal rated duties from 160 to 42,500 cu.ft./min. of dust-laden air.



Sr. J. Rubio, Spanish Minister of Education, opening the Congress. Seated on his right are the Rector of the University and Prof. Aguell y Aguell

# International Congress of Industrial Chemistry

By I. L. Hepner, \* Ph.D., A.C.G.I., A.M.I.Chem.E., A.I.R.I.

## REPORT OF THE 32nd CONGRESS RECENTLY HELD IN BARCELONA

THE Société de Chimie Industrielle, the French professional body similar to the British S.C.I., arranges an annual international congress in different parts of continental Europe. This year its 32nd congress was held in Barcelona from October 22 to 30. Both the organisation and the detailed planning for the congress were carried out entirely by the Spanish executive committee of the Société de Chimie Industrielle—in fact the brunt of the work fell upon several young research assistants in the University of Barcelona, notable amongst them was Dr. F. Sarratosa. This is the fourth time that this annual congress has been held in Spain and, once again, the Spanish executive committee was eager to demonstrate to foreign delegates that their local chemical industry is developing rapidly.

Barcelona, it must be added, is an ideal site for such a congress; this Mediterranean port has formed part

of the great European cultural history since the Roman era. Its many and splendid public buildings are evidence of the waves of civilizations—Roman, Phoenician, Gothic, Islamic, Renaissance and Baroque—that have shaped and moulded the personality of Barcelona over the centuries. It was most fitting, therefore, that in this centre of humanistic culture there should be held a congress devoted to one of the most important branches of scientific culture—the broad spectrum that is described as applied chemistry.

In a plenary session of the congress devoted to the future of chemical engineering in the U.S.A., Dr. Van Antwerpen, secretary of the American Institute of Chemical Engineers, defined the ideal chemical engineer as one who, besides being well versed in the fundamentals of science and engineering, was also deeply steeped in the general humanities. Barcelona, as a setting for such a congress was, therefore, in perfect keeping with this definition of the ideal chemical engineer.

The cynic will always remark that such international gatherings serve only as a professional and social meeting place between delegates from various places. However, this function is quite important in its own right,

especially in this age of specialised research where personal contact between research workers can save an enormous amount of futile work. To quote Voltaire: 'One hour's talk with a wise man is worth a thousand books'; not that the 2,000 delegates to this congress could, by any stretch of the imagination, all be considered wise men; nevertheless, the score or so of leading personalities present in Barcelona made this congress a memorable event.

It was also highly pleasing to note that most delegates to the Congress, whether from America, Japan or Russia, were constant and devoted readers of CPE.

### Congress opening

The ceremonial opening of the congress took place in the magnificent renaissance assembly hall of the University of Barcelona; it was presided over by the rector of the University, and the guest of honour was the Spanish Minister of Education, Sr. J. Rubio, who stressed the importance of this congress to Spanish technical education. M. Paul Toinet, president of the Société de Chemie Industrielle,

\* Editor, CHEMICAL & PROCESS ENGINEERING.

conveyed the greetings of the French Society and underlined the French ties with the Spanish chemical industry which are clearly evident. So, with great pomp, the congress was opened and delegates settled down to the hard business of reading and discussing over 150 communications which had been specially prepared for this event.

The congress was divided into 20 sections (apart from the plenary sessions where leading personalities read papers of general interest). These sections dealt with the following branches of applied and industrial chemistry: chemical engineering, corrosion, analytical chemistry, petrochemicals, nuclear technology, metallurgy, inorganic chemistry, materials of construction, heavy organic chemicals, pharmaceuticals, perfumes and cosmetics, rubbers and plastics, pulp and paper, textile dyeing and bleaching, tanning, food technology, agricultural chemistry and industrial hygiene. With such a wide range of topics it was too much to expect that all the papers presented would be of profound originality and interest; one can scarcely expect such original work to be steadily produced year after year for presentation at these annual congresses. Nevertheless, this did not excuse the abominably low standard of some of the papers which were not only devoid of scientific merit, but also atrociously presented.

Much of the blame must of necessity be placed at the feet of the scientific and technical executive committee of the congress who, after all, were responsible for scrutinising all papers. The impression was gained that only a minimum amount of scrutinising had been carried out and, what is even worse, the chairmen of various sections were often unacquainted with the papers presented in their own sections. On the other hand, a small proportion of papers were not only scientifically interesting but also well prepared and these probably rescued the reputation of the 1960 Barcelona congress.

#### Language difficulties

A great inconvenience experienced by most non-Spanish delegates was due to language difficulties. The majority of delegates (1,300) were Spanish and the second largest national group was French (300). The remaining delegates consisted of Americans, Russians (three), British (only six), Germans, Swiss, Italians, Belgians, Dutch, Danes and Japanese. Therefore, the main languages in which papers were read were Spanish and

French. It is to be expected that modern scientists and technologists should have a working knowledge of English, French and German; it would have been only fair, however, if some system of simultaneous translation had been arranged into French and English or that all the papers had been pre-printed in French. Neither of these courses were followed and, as a result, there was a distinct difficulty in effective communication for most non-Spanish delegates. In many ways this was the most regrettable feature of the whole congress.

Another tendency which somehow lowered the standard of the congress was a prevalence of papers with a marked sales bias. Such papers should never have been accepted by the publications committee.

It is virtually impossible to summarise all the papers presented at Barcelona and therefore only some of the papers of interest to chemical engineers will be reviewed in this article.

#### Fluidisation

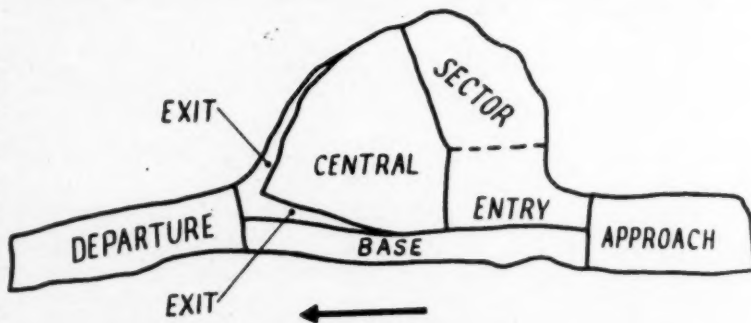
S. Konca-Djurdjevic discussed the influence of certain fluidisation factors on the electrification of fluidised particles. The author examined electrification of small corpuscles during fluidisation by measuring the potential difference between a metallic electrode

immersed in the fluidised bed and the grid at the base of the column. Despite the apparent complexity of this phenomenon, a simple relationship between various factors was determined and a significant difference between the composition of the fluidised material and matter deposited on the electrode was noted. As a result a new method for separating materials by different physical properties during fluidisation was suggested.

Reporting an investigation into the retention of the dispersed phase in a pulsating column, D. Defives and G. Schneider described a method which can be used to measure the retention between two plates in a pulsating column without disturbing it under operating conditions. They found that retention varies along the height of the column.

#### Solvent extraction

J. Durand *et al.* reported a study concerning the solvent extraction of uranyl nitrate. Transfer of uranyl nitrate from an aqueous to a solvent phase (tributyl phosphate) is accompanied by some transfer of nitric acid. Under these conditions, equilibrium conditions cannot be represented by a plain curve as this complicates the determination of the efficiency of the extractor. A simple method of measuring the column efficiency was



The Soviet delegation included two members of the Academy of Science, Prof. S. I. Volfkovich (left) and Prof. N. M. Zhavoronkov (right)





Delegates visiting the  
Cathedral of Barcelona

shown; this was based on determination of transfer of uranyl nitrate as well as nitric acid. Such a method, according to the authors, can be used for determining the concentration profile of a circulating phase in both uranyl nitrate and nitric acid.

Mass transfer in absorption processes was investigated by E. Costa Novella *et al.* by examining the absorption of dilute sulphur dioxide in water in a disc column. It was found that the influence of rate and relative gas velocity can be represented by the following equation:

$$K_G = 27L^{0.27} V^{0.67}$$

$$K_L = 5.3 \times 10^{-3} L^{0.8}$$

The effect of  $SO_2$  concentration and temperature on  $K_G$  was negligible. Results obtained with the system  $SO_2$ -air-water have been correlated in accordance with the general equations proposed for mass-transfer coefficients. These data were finally used in the calculation of commercial towers and fair agreement between theoretical and experimental data was obtained.

#### Mixing

Your editor, I. L. Hepner, together with G. N. Welding, presented a paper on the mechanism of mixing powders with plastic materials on a two-roll

mill. Flow of plastic materials between rolls occurs during mixing and calendaring—processes of considerable importance in the rubber and plastic industries which do not appear to have been systematically investigated from chemical engineering fundamentals. Although there has been some considerable study of the flow pattern of materials passing between rolls in the absence of a distinct bank, this investigation was solely concerned with determining the flow mechanism within the bank. Experiments were carried out by passing pale crepe rubber round one roll of a two-roll mill and adding a red dye to it.

By analysing the various banks of material formed just above the nip of the rolls, it was demonstrated that added material only penetrates as far as two-thirds of the thickness of the sheet—the remaining one-third (the dead layer) remains completely unmixed. Five regions of flow within the bank can be distinguished and these are shown in Fig. 1. The flow régime in each of these regions was derived by analysis of data and it is evident that flow within the bank is considerably more complex than had previously been assumed. The results of this analysis are of importance in



I. L. Hepner delivering his paper on mixing



Delegates at the Congress  
opening held at the University  
of Barcelona

the investigation of power requirements, breakdown of polymer and process of mixing.

### Growth of process engineering

R. Landau, in a paper discussing the role of engineering companies in development of chemical processes, traced the inception and growth of the modern process engineering company which first appeared about 30 years ago in the U.S.A., at that time specialising in process licensing and engineering in the petroleum field. Of more recent evolution is the engineering firm specialising in chemical engineering that, in addition to acting as an international source of licences and interchange of processes, has developed processes of its own available to all industry. Thus the co-operation between the process engineering company and chemical producer has often led to considerable mutual advantage in design engineering and process improvement.

### Marketing research

B. Cremers presented an analysis of a marketing research survey conducted in 1960, relating to chlorine and caustic soda consumption throughout the world. Installed plant capacities and actual production quantities for the year 1959 were given in this analysis. It was shown that, since 1930, the production of chlorine in the U.S.A. had increased by 400% and, since most chlorine is obtained by electrolysis of brine, caustic soda is produced as an important by-product; this has had a profound effect on caustic soda production. Thus, whereas in 1950 over 50% caustic soda was obtained from soda ash only 33% was so obtained in 1960. The total production of chlorine and caustic soda in the U.S.A. and Europe during 1959 is shown in the following table.

	Chlorine	Caustic soda
	Tons	Tons
U.S.A. ..	5,500,000	6,500,000
E.E.C.* ..	1,790,000	2,572,000
E.F.T.A.† ..	1,290,000	1,365,000
U.S.S.R. ..	697,000	1,633,000

\* The Six. † The Seven.

### C<sub>4</sub> hydrocarbons and other monomers

S. T. Ellis, reviewing the future of the American butene and butadiene industry, stated that the total 1959 production of butadiene in the U.S.A. was 1½ million tons, 67% of which was used for synthetic rubber production. At present an increasing number

of European countries are installing their own synthetic rubber plants so that the American industry is already producing too much butene and butadiene. All research in this American industry is therefore at present devoted to finding alternative outlets for C<sub>4</sub> hydrocarbons. There are already many promising applications, such as synthesis of maleic anhydride from butene or methacrylic acid synthesis from isobutylene. Co-polymers of ethylene and butene are becoming quite important due to their many useful properties.

In a paper devoted to the technical synthesis of some important monomers, J. W. Woolcock and K. W. Warne pointed out that, amongst organic raw materials, monomers form one of the most significant groups. It is always important to obtain an exceptional chemical purity of the monomer in order not to upset the subsequent polymerisation reaction and so alter the quality of the polymer. Often two or three important monomers are obtained together; this combination can sometimes be advantageous. However, industrial processes for obtaining monomers are highly competitive and must be economically feasible in order to survive.

### Drying of fertilisers

A new process of granulation applicable to the production of fertilisers was described by Y. Berquin. Drying and granulation was effected in a fluid phase by projection of the fertiliser particles to the base of a vertical conical chamber. At the same time the warm air stream is passed through the particles which are fluidised.

H. Huet reviewed current uranium production in France. The different stages in obtaining the uranium metal from the ore are: solution with nitric acid, purification by solvent extraction with a TBP-white spirit mixture, precipitation with ammonia, drying and calcination of UO<sub>3</sub>, reduction with hydrogen or cracked ammonia gas and fluorination with anhydrous fluorine acid.

### Conclusions

The range of topics discussed and debated at Barcelona was very wide; this can be seen from the random survey of the above papers with a chemical engineering bias. The congress could almost be likened to an enormous banquet where so much good fare is offered that guests are tempted to over-eat—and then suffer from acute indigestion! There was a distinct danger of succumbing to mental indigestion by participating in too many lectures. Undoubtedly, the

number of papers presented was too large and their average level was of too low a standard.

Organisers of future congresses under the auspices of the Société de Chimie Industrielle, would be well advised to limit the quantity of papers entered and, by stricter scrutinising, to raise their overall standard. Also, the number of sections should be reduced to not more than six; delegates could then be capable of absorbing a large proportion of all relevant subject matter. It must be emphasised that papers with a sales bias should under no condition be accepted in future. It was felt by many delegates that if further such sales papers were presented no serious research worker could be expected to write anything for publication on such a forum.

The most memorable lectures were those delivered at the plenary sessions—in the evening when most delegates were already tired after a long day's activity. Outstanding amongst these plenary lectures was Prof. Cathala's discourse on the functional analysis of chemical processes.

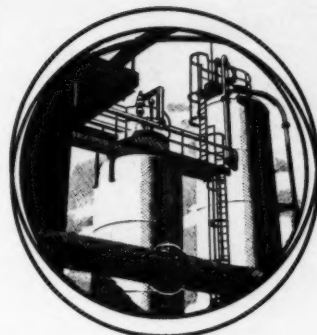
In another plenary session Dr. Van Antwerpen discussed the future of chemical engineering in the U.S.A. His lecture was a pellucid survey of the status of chemical engineering in a country that employs more chemical engineers than any other country in the world. It was a pity that the British Institution of Chemical Engineers was unrepresented in Barcelona; after all, Spain is in Europe and, although there are practically no facilities for training chemical engineers in Spain, the Spaniards should look to this country rather than the U.S.A. as soon as they are ready to start training chemical engineers.

The 32nd International Congress of Industrial Chemistry in the end gave an overall impression of breadth rather than depth; most aspects of industrial and applied chemistry were dealt with (though some only superficially). Undoubtedly such congresses provide a European forum for the chemical industry and in this age of a unified Europe, meetings of this kind will play an increasingly important role in the life of the technical and scientific worker engaged in chemistry and chemical engineering. The British Society of Chemical Industry might be well advised to co-operate more closely with the Société de Chimie Industrielle in future congresses, so that the influence of British applied chemistry and chemical engineering would be better felt in continental Europe.

# Materials of Construction for Chemical Plant

## TIMBER

By V. R. Gray,\* M.A., Ph.D.



*This is the eighth article in our series 'Materials of Construction for Chemical Plant'. So far the following materials have been discussed: PVC, lead, nickel, stainless steels, graphite, polyolefines and copper. In the construction of chemical plant timber is often overlooked. Chemical engineers receive little training in its use compared with their instruction in the properties of steel or concrete, moreover timber is not a product of the chemical industry like many of the newer plastics. It has a reputation for non-uniformity and difficulty of supply which is unjustified, since it can be graded and selected in exactly the same way as every other material. Chemical manufacturers should consider timber on its merits as a material for which extensive use can be found in chemical plant.*

**T**IMBER is one of man's oldest constructional materials and it continues to make a major contribution to most kinds of building construction. It is used most extensively, of course, in countries which have plentiful indigenous supplies, but even where supplies are limited or imported from abroad, timber retains its place in construction, particularly when modern techniques, such as the use of connectors or glued lamination, enable maximum economy in its use and frequently allow it to be used for purposes for which it could not previously be considered.

### Composition

Timber, in common with all naturally found materials, shows a wide variation in properties both between the different botanical species from which it comes and even within the same species. Grading and selection within a single species are needed to give material of high uniformity.

The largest botanical difference be-

tween timbers is that between the *Coniferae*, to which all the cone-bearing, narrow-leaf trees, or *softwoods*, belong, and the order *Dicotyledoneae*, broad-leaved trees or *hardwoods*. The difference is mainly one of structure and not necessarily of hardness or

specific gravity. The structure of a hardwood is much more complex than that of a softwood.

In its physical and chemical properties timber is essentially a cellular, orientated, high-polymeric material. The particular high-polymer complex

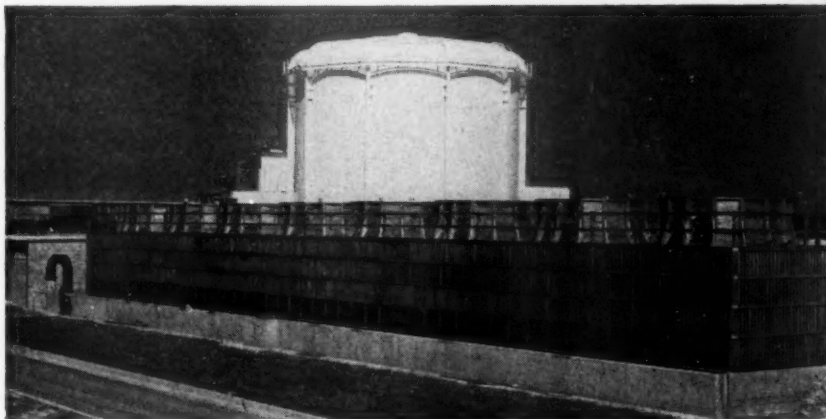


Fig. 5. Timber cooling tower (forced draught) used for cooling HIFAR nuclear research reactor of Australian Atomic Energy Commission

\*Timber Development Association Ltd.

[Courtesy: Head Wrightson Processes]



present in wood is rather complicated. The main constituent, cellulose, is 30 to 50% of the total wood substance depending on species, location and method of measuring it. It is fairly well understood chemically and has long been an important chemical product, being removed from the rest of the wood (or other plant) material to make paper, regenerated cellulose fibres or film, or cellulose plastics. The resistance of wood to chemicals is largely decided by the cellulose which provides its main structural units. Chemical resistance of wood is thus similar to that of cellophane or viscose rayon.

Lignin, the other main constituent of wood, is less understood chemically, though a great deal of work has been done towards discovering its chemical structure. It is usually considered to act as a binding material for the helical chains of cellulose making up the wood cells. It makes up some 20 to 40% of the wood substance and is a huge economic liability in pulping and cellulose mills, where it is discarded by the millions of tons.

The other constituents of wood include gums, sugars and low polymers related to cellulose which are usually water-soluble or hydrolysed readily, various phenolic substances and tannins which may confer resistance to decay, colouring matters which are often water-soluble, and some inorganic salts.

### Physical properties

Timber has three main advantages as a structural material. It has a high strength-to-weight ratio, a high strength-to-cost ratio and it is easily fabricated on site to give quite complicated shapes. It is also readily repaired and a good insulator. It is an anisotropic material, the greatest tensile strength, for instance, being in the grain direction.

Its most troublesome property is its dimensional alterations with changes in the humidity of its surroundings. These alterations are anisotropic, so that distortion as well as change of shape occurs. Timbers vary in the amount of movement and differential movement they display, but in all cases the timber should be seasoned or kiln-dried before use to a moisture content considered to be the average of the conditions it is likely to endure in practice. For exterior woodwork 18% moisture is usually recommended; for interior use 12%, or even less, is satisfactory.

The outside region of the tree, the sapwood, differs in some of its prop-

erties from the interior, the heartwood. It is frequently different in colour and usually more permeable to liquids. It contains a higher proportion of starches and sugars, and thus is more susceptible to biological attack.

### Preservation

Timber is subject to various forms of biological attack. In this country the main hazard is fungal decay, which will only attack susceptible timbers in damp conditions when the timber moisture content exceeds 20%.

Insect attack is mainly confined in this country to the common furniture beetle or woodworm (*Anobium punctatum*) and one or two other species which attack mainly sapwood or already rotted timber. The hazard is thus mainly (but not entirely) where high proportions of sapwood are present. Interior-grade plywood which is stuck with a protein adhesive is often susceptible to attack by woodworm.

In the tropics, termites may constitute a serious threat to timber and in the sea there may be various types of marine borers besides marine fungi. Where biological attack is likely, which in this country means damp conditions or sapwood, wood preservation should be considered. The most effective form of wood preservation is to impregnate the wood as deeply as possible with a toxic chemical in a vacuum and pressure treatment plant. Creosote is the traditional wood preservative and it still is difficult to surpass for many purposes. Non-leaching water-borne preservatives are available for use where the oily, stain-

ing and odoriferous qualities of creosote are not desired.<sup>1</sup>

With most timber species only the sapwood can be treated completely with preservative. Penetration into the heartwood is small and with some resistant species, such as Douglas fir, the timber may require to be incised to give adequate preservative penetration.

Various lesser treatments than vacuum and pressure impregnation, such as hot and cold tank immersion, steeping, dipping, brushing and spraying, may provide adequate protection against biological attack in particular instances. Organic solvent-type preservatives are particularly suited to treatment of timbers which are already in place and cannot be properly impregnated.

### Chemical corrosion

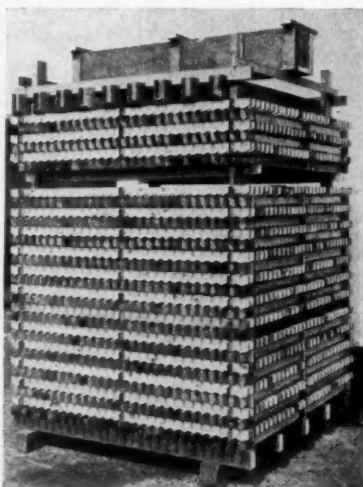
Timber does not corrode in the same way that metals do. It is, however, subject to three kinds of attack which can lead to its being rendered unsuitable for particular jobs.

Biological attack will not be treated further except to say that some types of biological attack resemble attack by chemicals and may be confused with it. This is particularly true of soft rot fungi or microfungi which soften the wood in a way very similar to attack by alkali.

The second form of disintegration may best be described as erosion. Wood exposed to the weather or to repeated wetting and drying cycles undergoes a detachment of surface fibres and a slow erosion. This is assisted by slow hydrolysis of the cellulose and lignin in the wood as well as leaching out of the more soluble materials. The erosion process is usually very slow and may amount to no more than a quarter of an inch in a hundred years. Even this can be prevented by regular painting.

A particular form of surface disintegration may result from wetting and drying cycles with inorganic salt solutions. The deposition of salt crystals within the timber may assist the disintegration so that it occurs more rapidly with salt solutions than with water.

The third method of breakdown of timber is the one which is mainly important for contact with chemical solutions, chemical attack. Water alone causes slow hydrolysis of timber, though the process is slow at room temperature and is usually only noticeable with hot water. The main value of timber for contact with chemicals



[Courtesy: Film Cooling Towers (1925) Ltd.]  
Fig. 4. Grid packing unit for 'film flow' cooling tower showing water distribution system

is in fact its good resistance to aqueous solutions, particularly when slightly acidic—conditions unsuited to mild steel. Timber itself is mildly acidic and it resists dilute mineral acids and concentrated weak acids, such as acetic acid, very well. Another valuable property of timber is its relative absence of harmful contaminating substances, particularly where food-stuffs or beverages are concerned. Its use for vessels and plant for food and beverages is thus well established and indeed in some cases the wood contributes an essential constituent to the beverage. The only drawback of this particular use is the porosity of the timber, which makes it difficult to clean out or sterilise.

### Unsuitable chemicals

Chemicals for which timber is definitely unsuitable are alkalis and oxidising agents. Alkalis dissolve several wood constituents, including the cellulose, and even weak solutions can cause slow disintegration. The use of ordinary washing solutions on timber surfaces must be restricted for this reason. Oxidising agents such as

chlorine, hypochlorites, nitrates, etc., attack the cellulose and lignin.

When considering what timber to use in a particular application, it is necessary to consider quality as well as the species and, of course, its availability at a reasonable price. Some species may be chosen as much for their availability in good quality as for their intrinsic resistance.

Suggested species for the various types of exposure are listed in Table 1. The names used are those recommended by British Standards 881 and 589 : 1955<sup>2</sup>, where the correct botanical names can also be found.

For exposure to damp or exterior conditions or ground contact, timber should either be treated with a preservative or be a durable species. The 'very durable' and 'durable' species in Table 1 are those listed in 'Handbook of Hardwoods'<sup>3</sup> and 'Handbook of Softwoods'.<sup>4</sup> Timbers suitable for particular uses in chemical plant are also listed in Table 1.

Quality of timber is particularly important for vats, tanks and other containers. Permeability of the timber must be at a minimum so that knots, checks and shakes must be absent as well as all sapwood. A few knots are permissible, as they can be removed and plugged. Straightness of grain is of great importance. Since, in general, softwoods give best acid resistance, it is necessary to find a

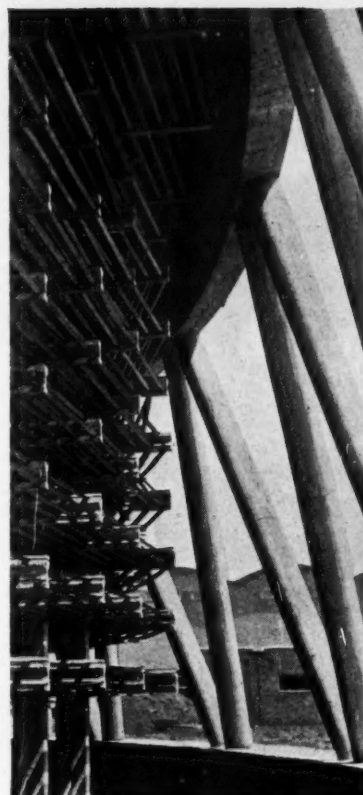
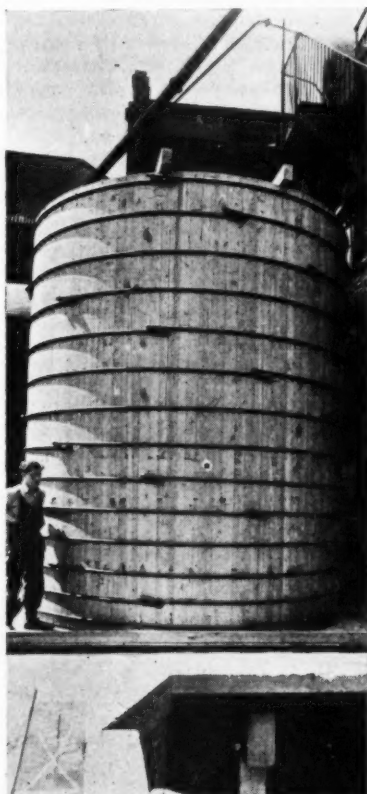


Fig. 2. View of the inside of a concrete water-cooling tower—the timber 'fill' from below



[Courtesy: Carly & Son Ltd.]

Fig. 1. A 10-ton fat-splitting vat made of 3-in. pitch pine

Table 1. Recommended timbers for use in chemical plant

Use	Recommended timbers
External exposure or damp conditions	<i>Very durable.</i> Afrormosia, afzelia, albizzia,* East African camphorwood, ekki, greenheart, iroko, ironbark,* kapur, makore, mansonina, okan, opepe, padauk, purpleheart, pyinkado, 'Rhodesian teak', rosewood,* tallowood, teak, wallaba. <i>Durable.</i> Agba, 'Central American cedar', sweet chestnut, eng, freijo, guarea, idigbo, jacareuba,* jarrah, jequitiba,* kempas, red louro,* American mahogany, dark-red meranti, mora, oak, rauli, robinia,* thitka, utile, cedar,* 'pencil cedar',* 'Port Orford cedar',* sequoia,* 'Southern cypress',* 'Western red cedar', 'yellow cedar', yew. <i>After preservative treatment.</i> European redwood, other timbers with high sapwood, exterior-grade plywood, beech, birch, maple.
Structures exposed to acid fumes	Pitch pine, teak, kauri,* oak, greenheart, Douglas fir, European redwood (sapwood-free)
Containers for acids	Pitch pine, Douglas fir, teak, oak, kauri,* sequoia,* 'Southern cypress',* ayan, white peroba, larch, afzelia, greenheart.
Plant requiring acid resistance	Ekki, greenheart, iroko, kauri,* pitch pine, purpleheart, pyinkado, Sydney blue gum,* 'Southern cypress',* teak, brush box, jarrah, karri, opepe.
Containers for mildly corrosive liquids	Pitch pine, Douglas fir, oak, Scots pine/redwood, sapele, idigbo, robinia,* afzelia, parana pine, krabak, podo, agba, danta, mansonina, East African camphorwood, muninga, 'yellow pine', plywood (exterior grade).

\* These timbers are not at present readily obtainable in this country.

softwood which can be bought free of sapwood. European redwood or Scots pine, the commonest softwood in this country, can only rarely be obtained free from sapwood in some Russian consignments. It is usually necessary to rely on pitch pine or, a cheaper alternative, Douglas fir.

Pitch pine, mainly obtained from the British West Indies, is the principal quality timber used for vats and containers. Traditional timbers such as kauri or 'southern cypress' are almost unobtainable. Pitch pine itself is difficult to obtain in the good quality. It varies in its resin content and it may be sorted into resinous and non-resinous boards, the former being most suitable for low-temperature uses and the latter for high temperatures where excess resin can be a nuisance.

'Douglas fir' or 'Columbian pine' has for some time been the most readily obtainable sapwood-free softwood. Freedom from sapwood is becoming more difficult, however. A peculiar difficulty with Douglas fir is its susceptibility to attack by a white pocket rot in the standing tree. Incipient attack by this rot is difficult to diagnose, but it may become active under the damp conditions of a vat in use, leading to premature failure.<sup>5</sup>

Oak is a traditional and still useful vat timber and, amongst recent timbers tried out, white peroba from South America has shown satisfactory properties. A recent Spanish investigation<sup>6</sup> on suitable timbers for acid resistance recommended ekki, a very hard, dense timber which is very difficult to machine but which is fairly readily obtainable and is already used to some extent for construction of filter press plates and frames.

Greenheart is a fairly readily available timber which can be used in various types of chemical plant, particularly for piling or continuous immersion. It readily develops splits and is difficult to keep dimensionally stable. Purpleheart is another durable timber which can be used, for instance, for filter plates and frames.

A number of timbers give coloured extracts in contact with alkali. They include afzelia, idigbo, opepe and afrormosia. Purpleheart can give a colour with acid.

#### Timber in chemical plant

Timber has been used as a traditional constructional material in chemical processes, particularly before means of fabrication of steel, concrete, etc., were developed. It has become particularly established in traditional chemical arts, such as production of

salt, dyeing, tanning and fermentation. Timber is particularly suitable for plant for aqueous liquids on the acid side of neutrality at not too high temperatures. It is favoured for foods and beverages as it contains no staining or contaminating substances.

The making of wooden containers is a craft which goes back to the beginning of civilisation. The craft of the cooper exists today in a form little changed for at least 1,000 years. It is today a declining craft, although there remains a steady demand for barrels, particularly for certain types of beverage.

#### Whisky maturing

The regulations for the manufacture of American whisky insist that it be matured in a new white oak barrel. Most wines and many spirits continue to be matured in oak barrels, though the lighter alcoholic beverages are undergoing a trend towards stainless steel, glass bottles and cans. Much alcoholic fermentation is still carried out in wooden fermenting vessels. Sterilisation of the wood is difficult, but the hops tend to discourage contamination and a proportion of the brewery trade use unlined timber, though lined vessels and stainless steel are now more general.

Another traditional chemical industry founded on the use of wooden vessels is the manufacture of vinegar. Acetic acid solutions corrode many metals and timber vessels are still used. Other traditional chemical processes whose development depended on wooden vessels and other equipment are tanning and dyeing.

The construction of vats and tanks

from timber is a craft almost as old as that of the cooper, though there has been some tendency to take advantage of modern materials. A vat is a cylindrical vessel bigger than a barrel and it can be as large as 600,000-gal. capacity. The tightness of the vessel is ensured by the use of adjustable steel hoops. Tanks are vessels of square shape which have to be kept tight by some form of pre-stressing. The use of timber is most common in the traditional chemical processes, to some extent because of a reluctance to change, but in many cases timber is the most suitable material for the job.

Besides fermentation of beverages, timber is used in the processing of several other foodstuffs, including pickles, olives, sauces, baked beans and lemon juice. Timber vessels are used for fat splitting by the traditional *Twitchell* process. The vessel used for this job is under considerable strain because shrinkage and swelling take place at the same time in different parts of the vessel (Fig. 1).

Tanning and dyeing still use a great deal of equipment made of timber. The manufacture of dry colours is carried out in wooden vessels. Water and brine may be stored in wooden vessels, sometimes in very large ones, possibly with concrete bases, the most vulnerable part of a timber vessel. The petroleum industry also employs timber storage vessels.

#### Water-cooling towers

Probably the greatest use of timber in chemical and allied plant in this country is in water-cooling towers. These are a comparatively recent development, as the demand of indus-

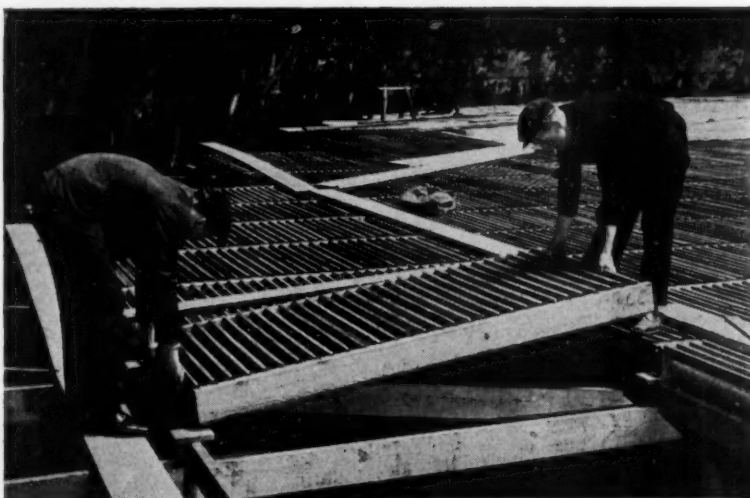


Fig. 3. Placing the mist eliminator units into position in a concrete water-cooling tower



trial water supplies for cooling has mainly taken place since the first world war. They were originally built completely of wood with creosoted timber for the framing and untreated slats for the 'fill' which breaks up the water and helps to evaporate it by the natural draught. The building of very large towers led to the use of concrete to make the exterior structure. The interior fill has always been made of timber and a great deal may be used in a single tower (Figs. 2 and 3).

The life of the timber in the early towers was affected by decay, so they were treated with water-borne preservatives. Recently it has become plain that the types of 'soft rot' fungi that attack timber in cooling towers can tolerate much higher preservative concentrations than the usual wood-destroying fungi and it has become necessary to specify higher retentions. Forced-draught cooling towers have developed greatly in recent years and many of these have special types of timber packing treated with preservatives (Figs. 4 and 5).

Timber is used to make up filter press plates and frames in a number of industries and it may be used in the construction of fume ducts or gas scrubbers with certain kinds of effluent. Stirrers may frequently be fabricated from timber.

In addition, timber may be used as a general constructional material in chemical plant, particularly where acid fumes are present.

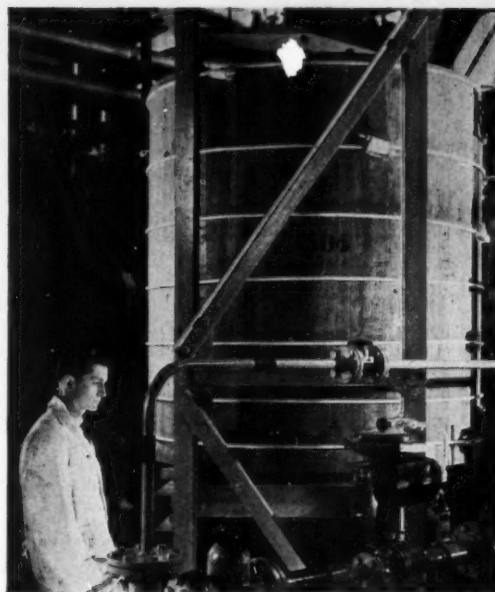
#### Lining of wooden vessels

Linings which may extend the range of use of wooden vessels include lead, copper, asphalt, polyester/fibre-glass, polyethylene and several other materials. There is no really satisfactory surface coating which can retard attack on timber plant, since none of them can withstand cyclic swelling and shrinking, so that the liquid ultimately penetrates the coating. Some useful protection may be given by treatment with paraffin wax, chlorinated rubber paints and other materials.

#### Future trends

The use of timber in chemical plant is thought by some firms to be increasing slightly. There is a definite, if limited, range of conditions where timber is the most suitable material and where it is likely to remain so. These conditions are dilute acids at moderate temperatures, where ease of fabrication and repair are important. Some replacement of timber by stainless steel, other metals or plastics is

Fig. 6. White peroba vat of 650-gal. capacity for containing polymer latex



[Courtesy: Monsanto Chemicals Ltd.]

occurring in the fermentation industries where the objection to timber is its difficulty in keeping the surface sterile. Even here a lined timber vessel is often the most satisfactory.

Stainless steel is always likely to be much more costly than timber for dilute acids. Plastic materials are an obvious competitor, but it is unlikely that they will ever be fabricated in really large sizes with the ease with which timber is. Transport considerations ensure that large vessels must be erected on the spot and chemical plant is essentially unlikely to provide much of a market for a standard plastic reaction vessel. Plastics are in any case likely to provide suitable linings for timber vessels. A recent example of how timber vessels can be incorporated into modern industry is their use for polymer latices (Fig. 6).<sup>7</sup>

With cooling towers there is at present a great deal of effort being exerted to replace the traditional timber filling by alternative materials. Asbestos sheet has had some success,

although the initial cost is higher than that of timber. Moulded plastics and phenolic-impregnated paper have both been advertised recently. Both are more costly than timber, but they are claimed to possess greater resistance to continuous leaching. The ultimate fungal breakdown of timber in a cooling tower is undoubtedly a weak point, but it is uncertain to what extent this can be prevented by the high preservative retentions used. It is possible that certain of the substitute materials offered may develop drawbacks under prolonged use.

Probably the most serious threat to timber as a packing in cooling towers is foamed plastics, for these, in addition to inertness, have the advantages of extreme lightness and of being much cheaper per unit volume. However, timber is likely to remain the preferred material for cooling tower packing for some time to come.

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- <sup>3</sup> 'A Handbook of Hardwoods', H.M.S.O., London, 1956.
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- <sup>5</sup> F. G. O. Pearson and C. Webster, 1958, 'Timbers used in Cooperage and the Manufacture of Vats and Filter Presses', D.S.I.R. and F.P.R.L.
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- <sup>7</sup> *Chemical Processing*, Dec. 1955.

The material of construction for chemical plant which will be discussed in next month's issue of  
CHEMICAL & PROCESS ENGINEERING  
will be

**PLATINUM**

# New Books

**Catalysis.** Vol. VII. By P. Emmett. Chapman & Hall Ltd. 108s.

Volume VII of 'Catalysis' is the final volume of a series edited by Prof. Emmett. These books have throughout combined a technological outlook with a pure theoretical interest, and must indeed be an invaluable series to those concerned with the many applications of catalysis upon which so much of industry depends. The present volume is concerned with several of these. The first chapter, contributed by the Shell research centre at Emeryville, reviews the present position of cracking catalysts in the petroleum industry and, in particular, discusses the various methods of preparation of alumina-silicate catalysts, their structure, chemical activation and stability in regeneration. This is a useful and complementary addition to the chapter on mechanisms of cracking discussed in Volume VI.

Winfield has provided an extensive review of dehydration-hydration catalysis, a subject which has hitherto been somewhat neglected owing to the declining production of alkenes by the dehydration of alcohols. Nevertheless, butadiene synthesis from alcohols and the hydration of unsaturated hydrocarbon gases are of considerable importance. A wide range of data has been collected and there are some 300 references. A recent method of measuring the otherwise inaccessible adsorption coefficients of alcohols, alkenes and water on the oxide catalysts is treated in some detail, though the method remains obscure in this review.

The remaining four chapters, all contributed by Dixon and Longfield of the American Cyanamid Co., cover oxidation catalysis. Hydrocarbons are discussed first at considerable length, particularly from the point of view of the production of maleic and phthalic anhydrides and ethylene oxide. A wide range of reactants, catalysts and conditions are covered. The abbreviations are slightly irritating and the units specified on p. 187 are not only clumsy but actually illogical. The chapter on the oxidation of  $\text{NH}_3$ , CO and  $\text{SO}_2$  is most interesting, two of the reactions being of fundamental importance in the chemicals industry, while the remaining, the oxidation of CO, is the most fully treated from a theoretical aspect.

It is difficult to see why the short account of electronic factors involved in oxidation catalysts has been placed in a separate chapter since these relate mostly to specific cases treated in the earlier chapters, and at the same time are not dealt with in sufficient detail to justify their standing alone. The book ends with what amounts to a footnote tabulating oxidation reactions of organic compounds other than hydrocarbons.

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Professor of Physical Chemistry,  
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**Chemical Instrumentation.** By H. A. Strobel. Addison-Wesley Ltd., 1960. 74s.

The many and varied techniques of chemical instrumentation analysis which have grown up in the last few decades do not seem hitherto to have been surveyed in a single volume. Workers in a particular field have not always appreciated the potentialities of other methods, so that a general survey of this kind is very welcome. Dr. Strobel has tried to bring together many instrumental methods with brief discussions on the underlying theories and the advantages and limitations of a particular technique. He has made a useful contribution to the science of chemical instrumentation.

The author opens with a brief survey of the general principles of instrument design including the relative advantages of single- and double-channel instruments, automatic and manual methods, etc. This section is followed by a chapter on errors of measurements; here emphasis is placed upon the distinction between the precision of a measurement and the accuracy of the final result—too often a confusion between these terms leads to an unquestioning acceptance of the answer given by an instrument.

The main body of the work is divided into two sections: Part I, so-called opticometric methods; and Part II, electrometric methods, this latter including radiochemistry. Part I deals with colorimetric and spectroscopic methods as well as such miscellaneous procedures as refractometry, polarimetry and light scattering. This section opens with a consideration of the emission, absorption and disper-

sion of electromagnetic radiation and then goes on to consider the emission and absorption of radiation by molecules. This section, however, contains a few errors: the P and R branches of molecular spectra are wrongly defined and the selection rules are very incompletely defined. In some cases a desire for compression has led to considerable obscurities (e.g. footnote on p. 59). Also, in connection with the Raman effect, the remarkable statement is made that hydrazine ( $\text{N}_2\text{H}_4$ ) does not absorb infra-red radiation! On p. 78 the point has been overlooked that Rayleigh scattering by air molecules is the major contribution to the blue colour of the sky. The theoretical section of Part I concludes with a survey of optics, interfacial effects and polarisation phenomena. There then follows an excellent survey of emission spectroscopy, absorptiometry, refractometry and polarimetry. In every case the scope of the method, analytical procedures and instrumentation techniques are well covered. Representative commercial instruments are described.

Part II opens with an elementary survey of electric and electrode phenomena and then continues with a comprehensive section on basic electronics. This contains a useful section on power supplies and filter circuits followed by brief comments on the triode, tetrode, pentode and thyatron. This section concludes with a chapter on semiconductors; here germanium diodes, zener diodes and transistors are well treated and comparisons drawn with conventional valves. The applications of electronics, d.c. and a.c. amplifiers, oscillators, oscilloscopes, etc., are next dealt with.

Chapters then follow describing polarography, coulometry, electrogravimetry and radiochemistry. In all of these the design and performance of instruments is effectively covered. However, the section on radiochemistry contains the surprising statement that proportional counters are supplanting Geiger counters. The paragraph dealing with the disposal of radioactive wastes is extremely inadequate and potentially dangerous—expert advice should always be obtained when dealing with this problem. The volume then closes with an appendix of laboratory experiments illustrating most of the instrumental techniques covered in this book.

A helpful feature of the entire work is the provision of many carefully chosen examples and problems together with suggestions for further reading to be found at the end of each

chapter. There are a number of minor errors throughout the text, some of which can be attributed to insufficient proof reading, *e.g.* a potential quoted in amp., cosine for sine, etc. These few minor blemishes, however, do not affect the general excellence of the work.

We feel that this work is a welcome contribution to chemical instrumentation and should find a place on many chemists' bookshelves—without, of course, supplanting specialist works in particular fields.

G. L. REED  
D. N. WATERS

### Sector-focused Cyclotrons.

Edited by F. T. Howard. Nuclear Science Series: Report No. 26. National Academy of Sciences—National Research Council, Washington, D.C., 1959.

At an informal conference held at See Island, Georgia, U.S.A., on February 2 to 4, 1959, an international group of cyclotron physicists met to exchange recent ideas and progress on 'Sector-focused Cyclotrons'. The meeting was promoted by the National Academy of Sciences under the chairmanship of A. H. Snell. The proceedings have now been edited by F. T. Howard and appear in the Nuclear Science Series of reports.

Cyclotron development has progressed in three stages. The first began with the construction of the constant frequency cyclotron by Lawrence at Berkeley in 1930. By 1938 many university physics departments had installed machines of this type. It was recognised that there were severe limitations in the energy range caused by the relativistic increase in mass. The second stage of development came after the war with the introduction of frequency modulation. At the expense of reduced beam intensity and pulsed operation it now became possible to extend the energy range to several hundred MeV.

Now interest has returned to lower energies with higher intensities. The principle from which recent research stems was described by L. H. Thomas in 1938, but was given little attention until 1949 when McMillan at Berkeley stimulated the construction of two electron models. In these cyclotrons constant frequency operation is retained by increasing the mean magnetic field with radius. This by itself would produce vertical instability of the particle motion. To overcome this, the magnetic field is made to vary with azimuth in the form of radial

ridges of high field separated by troughs of low field. The results of this research and similar work at Oak Ridge, U.S.A., were not published until 1956. Meantime, similar methods of focusing particles in azimuthally varying fields were proposed. Of particular interest for the present purpose is the method of 'spiral-ridged' focusing suggested by Kerst and Symon in 1956. By applying the latter technique to sector-focused cyclotrons the variation in field with azimuth can be considerably reduced.

It is clear that the dynamical problems presented by such complicated fields are considerable, and much of the research during the past few years has concentrated in obtaining a better appreciation of the various dangerous resonances which may occur.

Many groups in the United States, Russia and Europe have contributed to an understanding of this problem, and a number of specific proposals have been put forward. The most ambitious of these is by Oak Ridge for an 800-MeV cyclotron for protons. At the other end of the scale a number of groups have started construction of machines with energies less than 100 MeV—the report lists 11 in the United States and four in Europe. Of particular interest is the Oak Ridge heavy ion accelerator of roughly 60 in. diam. which should be capable of accelerating protons to 75 MeV.

The topics discussed at the conference ranged from theoretical aspects of the dynamics to operational experience on actual machines. Since the fields are non-linear, approximate linear theories have had to be supplemented by detailed computations on digital computers. The problem of designing magnets to realise the required fields and the measurement of the actual fields have required the development of new techniques. Again, increased flexibility has demanded greater novelty in the design of radio-frequency systems, and a greater attention to beam quality. From the spirit of the conference we can look forward with confidence to the successful completion of some of these machines in the near future.

W. WALKINSHAW.

**Travaux Pratiques de Physique Nucléaire et de Radiochimie.** By M. Duquesne, R. Gregoire and M. Lefort. Masson et Cie, Paris, 1960. Pp. 324 (in French).

This book has been produced at the request of the late Professor F. Joliot-Curie. It has been written for students of nuclear physics or chemistry of the Faculty of Sciences, Paris, and for others who wish to organise experimental courses. Following the interests of Prof. Joliot-Curie, the book emphasises both physical and chemical aspects of nuclear science.

The volume commences with an introduction discussing atomic and nuclear structure and interactions of radiations with matter. The quantisation of extranuclear electrons is considered briefly from the point of view of the Bohr theory. In such a short introduction the reviewer feels that wave-mechanical ideas rather than concepts of definite electron orbits should have been used.

The first major part of the book is concerned with the detection and measurement of nuclear radiations. Topics covered include details of various types of counters, statistical considerations in radioactivity measurements, the energies of radiations, and nuclear emulsions. A number of interesting experiments are presented. Included in this part of the book are small sections on the electrochemistry of radio-elements and on solvent extraction and chromatography.

The second major part of the book deals with methods for the study of nuclear structure. Subjects included are decay and growth of radionuclides, modes of disintegration and decay schemes,  $\alpha$ -,  $\beta$ - and  $\gamma$ -ray spectrometry, coincidence counting, nuclear reactions and 'hot-atom' chemistry. The book is concluded with appendices on health physics and on constants and systems of units. A number of problems are also provided.

It is interesting to learn from this book about the mode of experimental training in nuclear science employed by the Faculty of Sciences. A course based on the book should provide excellent experience. It is felt, however, that there are more suitable books for English-speaking students. There are also some errors, *e.g.* the captions to Figs. 115 and 116 should be exchanged. A volume of such weight (25 oz.) should be provided with a stronger cover and its usefulness be enhanced by the provision of a comprehensive index.

D. F. C. MORRIS

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**South Wales project**

British Hydrocarbon Chemicals Ltd. are developing plans for a major extension of their manufacturing activities at a new location in South Wales.

The proposed site, of several hundred acres, will be within a short distance of the B.P. refinery at Llandarcy, near Swansea, and the general pattern of operations can be expected to follow that at Grangemouth.

While no capital authorisations have yet been approved, initial investment is expected to be about £10 million.

**Electric power plant**

Pye Industries Ltd. of Australia and Petbow Ltd. of England have formed a joint Australian factory—Petbow Pty. Ltd. The new company will have a nominal capital of £250,000.

The English company manufacture engine-driven power plant including welding and generating equipment, floodlighting equipment, mobile workshops, switchboards, etc. This organisation has specialised over the last 30 years in the design and production of first-quality electric power plants.

The plant in Australia will gradually extend its operation to cover the whole Petbow range, also the manufacture of *Magnicon* alternators under licence to the Macfarlane Engineering Co. Ltd., Scotland.

**Northern Ireland's new industries**

I.C.I. Ltd. and the British Petroleum Co. Ltd. will build large plants in Northern Ireland in the near future.

I.C.I. have bought a 200-acre site at



*Aerial view of the Milford Haven refinery and marine jetty looking north*

Kilroot, near Carrickfergus, Co. Antrim, for a factory for the production of *Terylene* and possibly other man-made fibres.

On the opposite side of Belfast Lough, between Belfast and Holywood, Co. Down, B.P. intend to build an £8-million oil refinery to serve consumers in the United Kingdom and in some European countries.

I.C.I. will start building at Kilroot early next year, with a view to going into production in 1963.

**Milford Haven refinery**

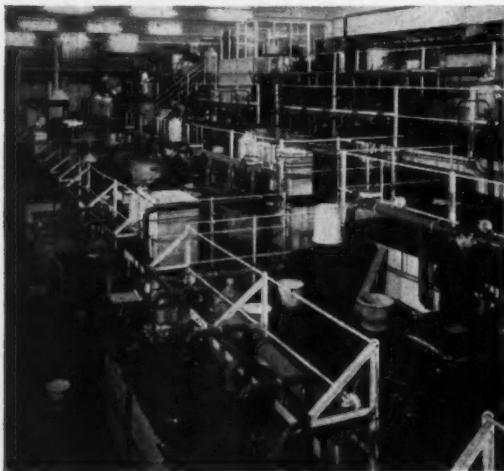
The new Esso refinery in Milford Haven which was started in July 1958 on a 350-acre site at the village of Herbrandston, about two miles west of Milford Haven town, was completed in October of this year.

The refinery has been designed to process initially 4½ million tons p.a. of crude oil with a staff of 330. The cost of construction was approximately £18 million.

The marine terminal can accommodate two tankers of up to 100,000 d.w.t. each, together with smaller coastal vessels. The approach trestle extends 3,500 ft. into the Haven.

There are four principal refining units: the primary crude oil distillation and light-ends recovery unit which physically separates the principal ingredients of the crude oil; the power-former which converts low-octane naphtha from the distillation process into high-octane motor spirit; the copper sweetening unit which removes certain unwanted compounds from both petrol and jet fuel; and the hydrofiner which removes sulphur from gas and diesel oils.

A feature of the refinery is that only air is used for the final cooling of hot products, which reduces the possibility of pollution.

**PIPE SYSTEM**

A complex system of unplasticised PVC fume extraction pipework, fabricated and installed by Extrudex Ltd. at the new Royston platinum refinery of Johnson Matthey & Co. Ltd., which has been working satisfactorily for three years. The ductwork extracts from a succession of refining pans highly corrosive fumes which are carried away through PVC eliminator boxes and scrubbing towers before release to the atmosphere.

# What's New



## in Plant • Equipment • Materials • Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

### **Welding electrodes**

Two additions to their range of arc-welding electrodes have been introduced by Lincoln Electric Co. Ltd.

The first of these, *NuFive*, is a smooth-flowing mild-steel electrode of the cellulose type designed for the welding of mild steel in all positions using a.c. or d.c. It is said to give good penetration qualities and, with its high melting rate and readily controlled slag, is suitable for pipe welding, using either the conventional or 'stovepipe' techniques.

The other addition is *NuSeven*, an electrode of the iron powder-rutile type for general application to the welding of mild steel in all positions.

A higher deposition efficiency compared with conventional titania-type electrodes, with a faster deposition rate and less stocking of the electrode, are amongst the advantages claimed for this electrode, enabling up to 30% more weld per electrode to be obtained, thus giving more arc time and so reducing production costs. Good slag control is said to render positional welding easier and in many applications the slag is self-releasing.

CPE 1597

### **Spark ignition torch**

A spark ignition torch, fed by liquefied petroleum gas, is claimed to be the solution to the difficulties of igniting automatic oil-fired industrial boilers. The principal difficulty which has been overcome has been flame instability caused by draught conditions normally present within this type of boiler.

Two sizes of spark ignition torch are offered by the industrial division of Calor Gas (Distribution) Co. Ltd. The smaller size gives a 7-in. flame, and the larger a flame 7 to 36 in. long. Both sizes work on a system of primary and secondary flame which it stabilises at its root.

These characteristics are said to give

the torch the following advantages over other systems of boiler ignition: certainty of ignition due to controlled mixture of gas and air; a long, wide, luminous flame which is stable in draught and withstands intense aeration; and a sparking plug which can be removed easily for cleaning without dismantling the torch. The sparking point is inside the nozzle where it is well protected against contamination by oil and carbon.

CPE 1598

### **Chemical changes in paint**

A new method of studying chemical changes in paints and other exterior coatings during outdoor exposure has been developed by the Goodyear Tire & Rubber Co.

By this method it is claimed that more durable paint materials can be

compounded. Previously, such studies were confined to laboratory infra-red tests, which utilised coated salt blocks. Because of the blocks' moisture sensitivity, this technique could not be used outdoors.

The new method uses the spectrum of coating materials deposited on highly reflective aluminium or tin-plated steel panels. The spectrum is recorded by an infra-red spectrophotometer before, during and after completion of outdoor exposure.

Measurements are made directly from the coated panels by means of a reflector on the spectrophotometer and, from the changes noted, the weathering rate is accurately measured.

CPE 1599

### **Adhesive for tank linings**

A new adhesive offered by Polymer Corporation, *Bondmaster G523*, is said to be suitable for tank lining applications. It is a high-bond-strength, non-curing, room-temperature-contact bonding, liquid adhesive for rigid and semi-rigid materials such as decorative laminate linoleum, metals, most plastics (except plasticised vinyls), some rubber stocks, wood, plaster, composition board, leather and foam and sponge rubbers.

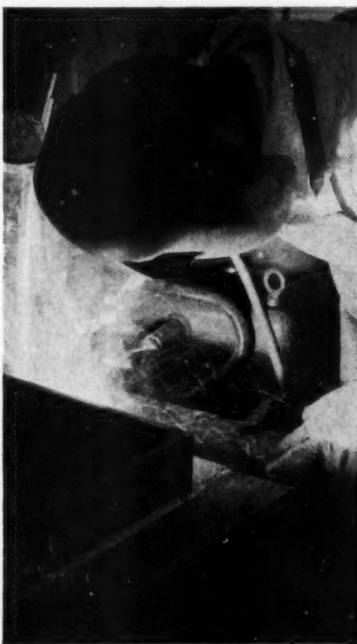
CPE 1600

### **PVC sintering powder**

The success of polyethylene sintering powders has prompted manufacturers to investigate the possibility of producing sintering powders from other plastics. The usual method of obtaining PVC coatings on metal articles is by hot-dip coating into PVC paste or, in a few cases, the application of the coating by crosshead extrusion and subsequent fabrication.

Vinatex Ltd. offer *Vinacoat* sintering powders in two grades which produce PVC coatings of 75 and 80 Shore hardness.

All powders are sieved through



Horizontal fillet welding with NuSeven on a typical production application

30-mesh screens. This is said to give a particle size which ensures optimum sintering characteristics. **CPE 1601**

### Vacuum shelf drier

A compact and self-contained vacuum shelf drier is offered by the drying and distillation research division of Edwards High Vacuum Ltd. It has been designed to meet the need for a research and pilot plant capable of smoothing out production difficulties before employing larger driers. However, its capacity is large enough to enable it to be used for production purposes and the first models are already being used for drying concentrated fruit juices and various types of vaccines.

An advantage claimed for this drier is the fact that the complete process from initial drying to final stoppering can be carried out under vacuum in one cycle. **CPE 1602**

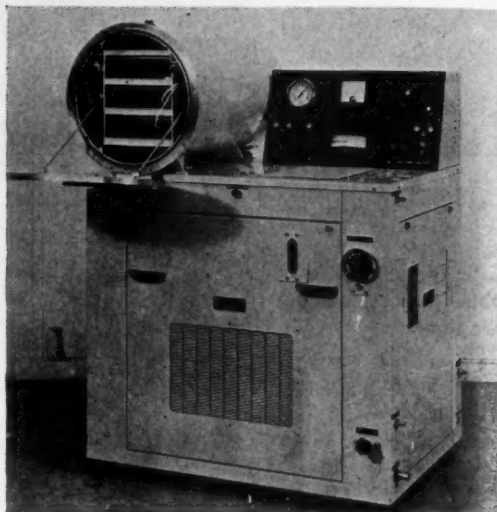
### Temperature and operation recorders

A range of self-contained, portable temperature and operation recorders is offered by Shandon Scientific Co. Ltd.

Models are available for recording ambient temperature, for remote temperature recording, for operation recording and for the simultaneous recording of both temperature and operation.

These *Tempscribe* recorders are 5½ in. wide × 4½ in. deep × 7½ in. high. They consist basically of two parts—the *Bakelite* case containing the spring-driven clock mechanism, and a front

Self-contained drier for research and pilot plant



Portable temperature and operation recorder

panel or 'door' carrying the pen and actuating mechanism.

For recording ambient temperature, the door contains a bimetallic element. For remote temperature recording, a bulb-type element is connected to the door by 6 ft. of flexible capillary tubing, while for operation recording the door carries an electro-magnetic armature for parallel connection to the circuit concerned. The door for the temperature/operation recorder contains both a bulb-type element and an electro-magnetic armature, each actuating a separate pen.

The doors are interchangeable and, within certain limits (imposed by the rotation time of the clock mechanism), any recorder can be converted to perform a different function.

**CPE 1603**

### Vibratory screens

A light-type vibratory screen with resilient mounting in bonded rubber brushes, is offered by Saxon Engineering Co. Ltd.

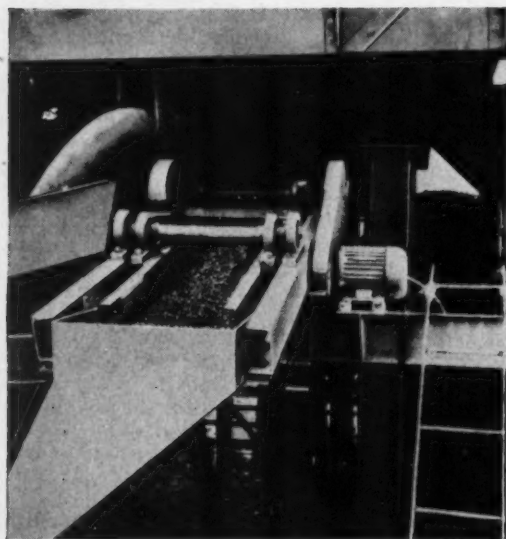
Sizes up to 10 × 4 ft. are available with a maximum power requirement of 3 h.p. The amplitude of vibration is variable and, where required, models can be supplied arranged for double-deck screening and also for mobility.

When dealing with fine materials where the moisture content could cause blinding, the screen can be adapted for thermal deck heating which prevents this condition.

**CPE 1604**

### Boronated bitumen

Berry Wiggins & Co. Ltd. have produced with the co-operation of Borax Consolidated Ltd. a range of boronated bitumen compounds. Of



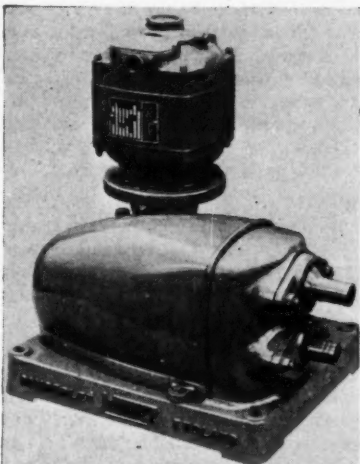
Resiliently mounted vibratory screen in operation at a quarry rejecting sand ½ in. (wet screening)



these, *Kingsnorth* compound No. 2028 is offered for use as a biological shield in nuclear reactors.

It contains a bitumen-soluble boron compound which is said to be free from problems associated with sedimentation. It is claimed that the presence of boron in combination with hydrogen in this new material will, when used at the recommended thicknesses, ensure complete attenuation and absorption of slow neutrons.

**CPE 1605**



#### PUMPING SMALL QUANTITIES

A pump intended for the pumping of relatively small quantities of chemicals and of fine slurries is the 1-in. model of the Linatex diaphragm pump offered by Wilkinson Rubber Linatex Ltd. The pump can operate in the range 30 gal./hr. to 120 gal./hr. There is a protected pump body, a diaphragm and solid valves. The drive is made from a vertically mounted motor and gearbox and stroke adjustment on the crank arm is provided. **CPE 1606**

#### Liquid detergent

A liquid detergent for cleaning all types of machines and hard surfaces that require removal of grease and dirt is offered by D. A. Stuart Oil Co. (G.B.) Ltd.

In its various forms *Dasco Kleen* can be used in either cold or hot fresh water or with sea-water. The manufacturers claim that its advantages are that it requires no stirring, it is strong enough for the heaviest industrial cleaning and will not remove paint nor harm the skin. Moreover, it can be applied efficiently on to any surface by using a spray gun.

**CPE 1607**

#### Field trial for optimising controller

A self-adaptive optimising controller, *Optimat*, made by Panellit Ltd., is about to undergo a field trial at the oil refinery of one of the largest petroleum distributors in the U.K.

The controller will optimise the process parameters of a distillation column for maximum output at the same time maintaining the quality specification of the refined spirit. The quality of the end product will be analysed by an on-stream process chromatograph.

The instrument is basically a small-scale, special-purpose digital computer accepting input signals from the process and optimising plant performance by operating on the set points of up to three conventional three-term controllers. It is always seeking to improve plant performance and operates by making smallstep changes to the set points of the plant variables, assessing the result of each move before making the next.

In this way it is claimed that the plant is steered towards optimum operating conditions taking into account operating point changes due to such uncontrollable variables as demand, ageing of catalyst, quality of raw materials, ambient temperature, etc., and no knowledge of process transfer functions is necessary.

**CPE 1608**

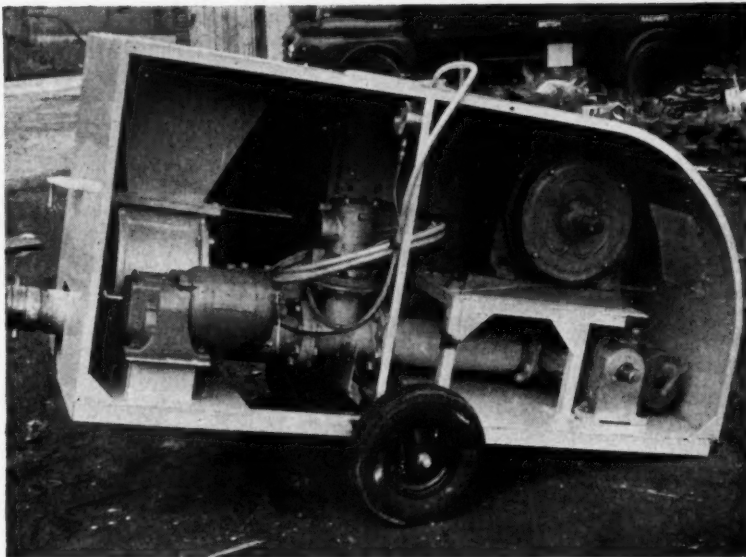
#### Cooling machine

A *Phillips* four-cylinder, universal cooling machine, designed to meet the need in industrial processes for large-capacity, low-temperature refrigeration units, is offered by Research & Control Instruments Ltd.

The unit is said to be suitable for direct condensation in distillation processes, liquid and gas stream cooling,

and for industrial operations calling for refrigeration in the temperature range down to  $-200^{\circ}\text{C}.$ , and at a pressure range up to 450 p.s.i.

An auxiliary unit is also available for the production of liquid air directly from the atmosphere. In addition, a fractionating column to produce liquid nitrogen is under development. **CPE 1609**



#### MOBILE PNEUMATIC CONVEYOR

A unit which saves permanent installation of bucket and screw conveyors is offered by F. E. Callow (Engineers) Ltd. This is a mobile air conveying unit which can be moved about the works and connected up with flexible piping or standard steam tubing, to take the material up, over and around into storage hoppers or mixers. This is said to make the system more adaptable with a prime mover which is readily moved about and a pipework easily installed and removed to another site as required. The picture shows a unit with the side panel removed. The pulleys and belts have been removed from the electric motor and compressor for clarity. **CPE 1610**

# Personal Paragraphs

★ **Mr. L. Atkinson** and **Mr. A. King** have been appointed to the divisional board of the Winthrop Laboratories division of the Winthrop group at Newcastle upon Tyne.

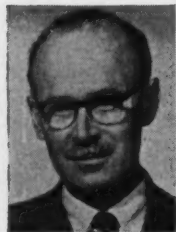
★ **Mr. W. T. Flower**, sales director of Bailey Meters & Controls Ltd., has been appointed deputy managing director.

★ **Mr. A. E. Richards** has been appointed managing director of Universal Matthey Products Ltd., the joint subsidiary company of Universal Oil Products Co. and Johnson, Matthey & Co. Ltd.

★ **Mr. F. Ashworth** has been appointed works manager of the Reddish Chemical Co. Ltd. He was previously production manager of Wm. Blyth & Co., heavy chemical manufacturers.



F. Ashworth



N. E. F. Hitchcock



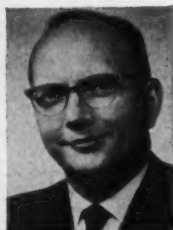
D. J. Hodgson

★ **Mr. P. A. M. Curry** has been appointed deputy to the head of the government and industrial valve division of Mullard Ltd.

★ Board changes have taken place at Woodhall-Duckham Construction Co. Ltd. **Mr. J. Simpson** has become deputy chairman (group), **Mr. E. N. Wenborn** has become vice-chairman and **Mr. C. D. Muntz** has been appointed joint managing director. **Mr. H. E. Dyble**, **Mr. A. F. Cottrell** and **Mr. R. O. Richards** have joined the board.

★ **Mr. E. S. Sellers**, head of the B.P. research centre at Sunbury-on-Thames, has accepted the invitation to become president of the Junior Institution of Engineers for 1960-61.

★ **Mr. C. F. Fullgraf** has assumed responsibilities as managing director of Thomas Hedley & Co. Ltd. Before his appointment he was managing director of the toilet goods division of Procter & Gamble Co., the parent company. He joined the company in 1939. **Mr. K. W. Streith**, who has been Hedley's managing director since 1958, is on leave of absence on a special assignment to develop further Hedley's export business with particular emphasis on the Outer Seven. He will remain a director of the company.



C. M. Fullgraf

★ **Mr. N. E. F. Hitchcock** has been appointed laboratory manager of the Castrol Group's main research establishment at Hayes in succession to the late **Mr. P. W. L. Gossling**. He is to hold this office in addition to that of group development chemist, which position he has occupied for the last nine years. He has been with the group 32 years.



A. D. McKnight, C.B.E.

★ The board of governors of the International Atomic Energy Agency has elected **Mr. A. D. McKnight**, C.B.E., of Australia, chairman of the board for 1960-61. His previous posts have included that of secretary, Department of Army, lecturer in law and member of the council of Canberra University College.

★ Senior staff appointments have been made by B.T.R. Industries. **Mr. J. A. Hardman** has been appointed general manager of the belting division, **Mr. D. J. Hodgson** controller of research, and **Mr. L. W. Rodway** manager of market research and development.

★ The Council of the Textile Institute has unanimously resolved that the status of Companion Member be granted to **Mr. F. C. Bagnall**, C.B.E.,

managing director of British Nylon Spinners Ltd.; to **Mr. N. G. McCulloch**, C.B.E., who was deputy chairman of the Calico Printers' Association till 1953 and chairman of the Council of the British Cotton Industry Research Association from 1949 to 1960; and to **Mr. W. R. Wadsworth**, O.B.E., managing director of W. Frost Ltd.

★ **Dr. J. C. Hudson**, who has been in charge of the British Iron and Steel Research Association's research on corrosion since the formation of the association in 1945, retired at the end of August. He will continue to have close ties with the association since he has agreed to act as consultant to both the corrosion advice bureau and the chemistry department. He is succeeded by **Mr. J. F. Stanners**.

★ **Mr. P. J. Daglish** has been appointed special executive responsible to the managing director of D. Napier & Sons Ltd., a member of the English Electric group. He has been with the group since 1946.

★ **Mr. J. E. B. Greeves** has been appointed to the board of Bramigk & Co. Ltd. in the capacity of assistant managing director. He has spent several years in Canada where he was till recently chairman and managing director of Fry-Cadbury Ltd.

★ **Mr. W. A. Ankerson** has joined the board of A.E.I. (Woolwich) Ltd. as assistant managing director. He will relinquish his appointment as general manager of A.E.I. home district offices and will cease to be a director of A.E.I. Overseas Ltd.

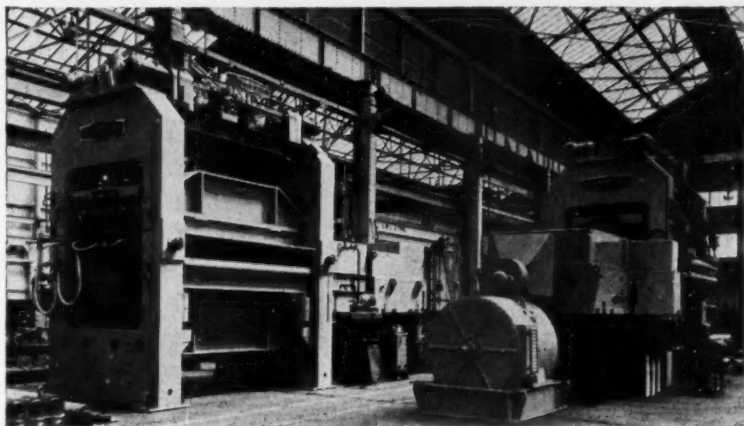
★ **Mr. E. J. Earnshaw** has resigned from the board of the Plessey Co. Ltd.

★ **Mr. H. A. White** has been appointed to the newly created position of assistant managing director of Hercules Powder Co. Ltd. Before coming to England in 1952 he was with the Paper Makers Chemical department of the Hercules Powder Co. (Canada) Ltd.

★ **Mr. B. J. Phipp**, technical sales manager of Artite Resins Ltd., has been appointed technical manager, and **Mr. P. Harryman** the marketing manager.

★ **Mr. D. R. S. Turner** has been appointed a director and general manager of Davidson & Co. Ltd. He has been in charge of the development of the A.E.I. works in Larne from 1953-58. Since 1958 he has been commercial manager of the turbine generator division of A.E.I. (Manchester) Ltd.

# Orders and Contracts



On the left is a nine-roll backed-up leveller for hot plates  $1\frac{1}{2}$  in. thick and 10 ft. 6 in. wide. On the right is an 11-roll backed-up leveller for cold plates up to  $\frac{3}{4}$  in. thick  $\times$  10 ft. 6 in. wide. Both were supplied by Head Wrightson Machine Co. Ltd. to Consett Iron Co. Ltd. for their new plate mill

## Plate levellers

Following a contract for five heavy plate roller levellers for the new plate mills at South Durham Steel & Iron Co. Ltd. and Consett Iron Co. Ltd., the Head Wrightson Machine Co. Ltd. have received an order from Colvilles Ltd. for an 11-roll backed-up roller leveller for dealing with hot steel plates up to 1 in. thick  $\times$  10 ft. 6 in. wide.

A further order has been received from Consett Iron Co. for a second nine-roll backed-up leveller capable of handling hot plates up to  $1\frac{1}{2}$  in. thick  $\times$  10 ft. 6 in. wide.

The total value for contracts received recently for plate levellers for the steel industry amounts to about £550,000.

## Ethylene and ethylene oxide plant

SunOlin Chemical Co. has awarded engineering and construction contracts to the Lummus Co. for a \$20-million ethylene and ethylene oxide plant adjacent to the Sun Oil Co. refinery at Marcus Hook, Pa., U.S.A.

The new plant, scheduled for completion late next year, will have a capacity of 225 million lb. p.a. of ethylene and 55 million lb. p.a. of ethylene oxide.

The new plant and related facilities also will produce 12 million cu.ft./day of high-purity hydrogen and up to 1 million cu.ft./day of carbon monoxide.

Included in the expansion programme is a multiple pipeline system that will cross the Delaware River to

New Jersey. This will enable quick delivery of petrochemical raw materials and intermediates to existing companies and others in the area.

## Automatic computer

Electricite de France has given an order to Compagnie Europeenne d'Automatisme Electronique for an automatic computer control system for the first unit of its steam power plant to be built at Saint-Ouen. The first installation will have a power output of 25 MW. Both coal and natural gas are to be used as fuels. The order includes two digital control computers with associated peripheral equipment. This will be used to record and automatically monitor more than 600 process variables. They will also calculate and record theoretical and actual performance values and carry optimum control of the plant to give the desired power output at a minimum cost.

## Mass spectrometers

An order valued £50,000 has been received by the instrumentation division of A.E.I. Ltd. from a London confirming house for two MS7 spark-source mass spectrometers for Russia. The spectrometers will be manufactured at the A.E.I. Trafford Park works and will be delivered to V/O Mashpriborintorg, U.S.S.R.

The spectrometer was the first commercially available spark-source instrument and was designed for the determination and analysis of impuri-

ties in inorganic solids such as metals, semi-conductors, graphite and other materials of interest to nuclear and electronic engineers. The sensitivity of the instrument is such that many elements can be detected at the level of 0.001 p.p.m. (atomic), and in certain circumstances the sensitivity can be increased even further.

## Drying and cooling plant

The A.P.V. Co. Ltd. have concluded an agreement with Anhydro A/S of Copenhagen, Denmark, for the sale by A.P.V. Co. Ltd. in Great Britain and in a large part of the world of Anhydro spray drying and cooling plant.

This agreement provides the British company with plant which is complementary to their evaporators in installations for the dehydration of liquids.

## Distillation units

Export orders totalling £25,000 have been received by Winston Electronics Ltd. from the U.S., Germany, Italy and Aden for the B.P. 14-plate distillation unit used for rapid economic assay of crude oil and for laboratory distillation work in organic chemistry.

The equipment was developed in the laboratories of British Petroleum Co. Ltd.

## Turbo-blower

The General Electric Co. Ltd. has received an order valued at £139,000 for the supply and installation of a turbo-blower at the Cleveland works of Dorman Long (Steel) Ltd.

The machine, which is to supply air to blast furnaces, will be of the centrifugal type, having three impellers each of 66 in. diam. running at speeds up to 3,200 r.p.m. The output at normal duty will be 100,000 cu.ft./min. against a pressure of 35 p.s.i.g. and at maximum duty 110,000 cu.ft./min. against a pressure of 40 p.s.i.g.

The drive will be provided by a steam turbine, direct coupled to the blower, operating on steam conditions of 425 p.s.i.g. at 725°F. Condensing plant will be supplied by Mirreles Watson Ltd., of Glasgow.

## Detergent manufacture

Constructors John Brown Ltd., in association with Marchon Products Ltd., have been awarded contracts by Techmashimport, Moscow, totalling nearly £3 million for the design, supply of equipment and the commissioning of two factories to manufacture raw materials for detergents.

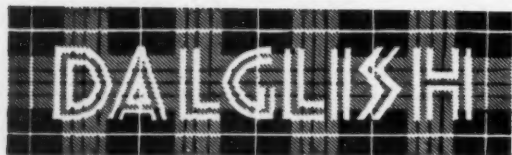


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## THAILAND

**Catalytic cracking unit**

The first catalytic petroleum installation of any kind in Thailand has been licensed by Houdry Process Corporation to the Defense Energy Department of the Government of Thailand.

The catalytic cracking unit, which will operate at high conversion levels, will provide raw materials for manufacturing aviation and high-quality motor fuel. It will be built on the Chao Phraya River outside Bangkok.

Completion is planned for late next year. The unit will have a licence capacity of 2,000 bbl./day of fresh feed.

## KENYA

**Pyrethrum plant extension**

Extensions now being made to the plant of the Pyrethrum Board at Nakuru, used for the extraction of insecticide from pyrethrum flowers, will bring the total production capacity in Kenya up to 16,000 tons p.a. of flowers.

A feature of the new plant, to be built alongside the existing factory, will be a huge warehouse having an elliptical roof with no floor supports, giving the maximum of uninterrupted floor space.

## PUERTO RICO

**Polyethylene facility**

A polyethylene plant will be constructed and operated by Union Carbide Inc. It will be adjacent to the existing chemical plant of the company, near Ponce, on the southern coast of Puerto Rico, which went on stream in mid-1959. The plant will have the largest initial capacity of any polyethylene plant in the world—110 million lb. p.a.

It is expected that the new production unit, which will serve world markets, will begin operation during the second half of 1962.

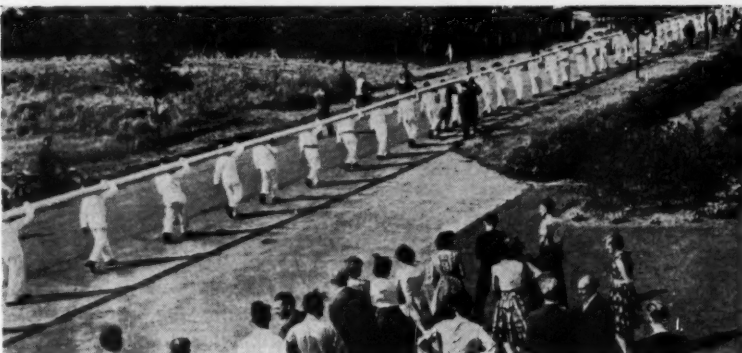
Together with the existing chemicals unit, the combined facility represents the largest single industrial investment in Puerto Rico.

## SWITZERLAND

**Plastics design laboratory**

A new plastics design laboratory is to be built in Geneva by Du Pont de Nemours International S.A.

Purpose of the laboratory is to help European manufacturers develop new



## NETHERLANDS

*The picture shows a PVC length of 7-in. diam. pipe 350 ft. long which was made by the Wavin company of Hardenberg for the N.A.M. oil-producing company. It is needed to drain off the salt water which is produced with the oil from wells near Rotterdam.*

*The pipe was manufactured in one piece to prevent possible leakages which might damage the surrounding land.*

*There were several problems created by the length. To move it to the railway station it was carried on the shoulders of 55 men to the railway goods yard where nine open freight cars had been specially equipped with wooden blocks on which the pipe was laid. At the factory a hole had to be knocked in the wall as the pipe grew longer.*

applications, primarily for Delrin acetal resin and Teflon TFE and FEP fluorocarbon resins. It will also provide new ideas on the use of the company's plastics and will handle specific requests from customers.

The new facility, which is expected to be ready by April 1961, will consist of an application design section, a model or machine shop and a chemical and physical testing area.

**Chemical engineering congress**

The first part of the third congress of the European Congress Federation of Chemical Engineering will be held in London from June 20 to 26, 1962, on the occasion of the Chemical and Petroleum Engineering Exhibition at Olympia. The major event in the programme is a three-day meeting organised by the Institution of Chemical Engineers on the interaction between fluids and particles.

Suggestions for papers for inclusion in the programme are invited. Title or subject, and summary or other brief description should be sent to the general secretary, Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1, not later than April 30, 1961.

## ITALY

**Houdry process unit**

A Houdry dehydrogenation process unit with a nominal design capacity of 20,000 short tons p.a. of butadiene is on stream at ANIC of Italy in Ravenna. The company which used the butadiene also has a plant for synthetic rubber at the Ravenna site.

ANIC is controlled by E.N.I. (Ente Nazionale Idrocarburi), an economic agency established by the Italian state, which is sole lessee in prospecting, extracting and transporting oil and gas in the Po valley. E.N.I. also promotes and operates national interest projects in the field of hydrocarbons over all Italian territory.

## DOMINICAN REPUBLIC

**Furfural from sugar**

In the four years since its inauguration the furfural plant of Central Romana By-Products has produced 50.5 million kg. of furfural from sugar cane waste which has been sold for \$9.2 million. Production figures have risen from 8.2 million kg. in 1956 to 16.7 million kg. in 1959, although since 1956 the price of furfural has fallen somewhat. Production for 1960 will be an estimated 19 million kg.



# Nuclear Notes

## Packing fuel elements

A 24,000-W amplifier and giant speaker system similar to a gramophone, but nearly 1,000 times more powerful, is being used to pack nuclear fuel elements at the U.S. Atomic Energy Commission's Hanford plant operated by U.S. General Electric.

The new method is called 'vibrational compaction'. It simultaneously compacts and clads ceramic fuel materials in a manner described as rapid, simple and flexible. The process is expected to make a substantial reduction in the cost of fuel element construction.

The 'loud-speaker' or vibrator portion of the equipment is driven by a large electro-magnet delivering a thrust of nearly 5,000 lb. Fuel element cladding in the form of tubes up to 8 ft. in length are attached to the vibrator. As nuclear fuel powder is poured into them, the tubes are vibrated at frequencies ranging between 5 and 5,000 c/s., compacting the fuel to more than 90% of its theoretical density in about 3 min.

## Leak detection

A method for detecting leaks at a rate of less than one sixty-millionth part cu.in./day was illustrated in the U.K.A.E.A.'s exhibit at the 5th International Instruments and Measurements Exhibition in Stockholm. The method, which uses a radioisotope technique, has been developed by the Wantage research laboratory.

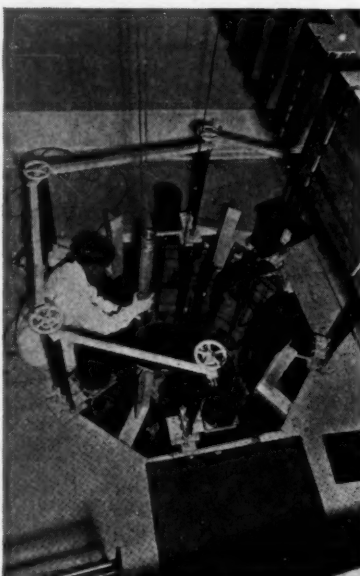
Corresponding to a cube of about one four-hundredth in. side, a sixty-millionth cu. in. appears to be a very small volume, yet it can contain seven million million atoms of the radioactive gas used in this particular application.

Since, initially, some 16,000 of these atoms would decay and emit tell-tale radiation each second, detection of their presence and calculation of the rate of leakage can be carried out with comparative ease.

To determine the rate at which leaks in sealed components would admit air or other gases, these are immersed in an atmosphere of radioactive krypton-85 gas which is raised to a known pressure for a fixed period of time. After the components have been removed from the gas, the

amounts of krypton which have found their way into the objects under test are determined by measuring the emitted radiation with a counter.

For outward leakage, the component is filled to the required pressure with a known specific activity of the gas. Then, either the escaping gas is collected and assayed with a counter, or measurements are made of the decrease over a period of time in the intensity of radiation emitted from the component. The latter is the most reliable method, as a leak can become temporarily blocked.



Looking into the core of the ZENITH reactor. The reactor is being used initially to obtain data for the DRAGON project. Some 90 European engineers and scientists, together with 160 from the U.K., comprise the international staff of the O.E.E.C. DRAGON project at the U.K.A.E.A. atomic energy establishment at Winfrith

## Radioisotope centre in Middle East

The board of governors of International Atomic Energy Agency has endorsed a request from the United Arab Republic for the establishment in Cairo of a Middle Eastern regional radioisotope centre for the Arab countries, subject to the holding beforehand of a series of training courses in Cairo.

The board decided to defer requests from Belgium (on behalf of the Congo), Greece and Turkey for the establishment of such centres and an offer by Israel to act as host for such a centre if the board so wished. This action was taken without prejudice to the director-general's right to hold training courses in these or other member states.

## Waste disposal

Euratom has given a favourable opinion on a French proposal for an experiment in dumping containers of radioactive waste in the Mediterranean. Member countries are required to communicate to Euratom all proposals for waste disposal. The French plan, which has been examined by 11 experts on behalf of Euratom, involves the dumping in the Mediterranean of 6,500 containers of radioactive waste from the Marcoule Atomic Centre. The site of the experiment will be a submarine trough between Corsica and Nice. Euratom and Italian specialists will also be taking part in the experiment, which is expected to take place in October.

M. Francis Perrin, a member of the Scientific and Technical Committee, said that as it is taking place at a depth of 2,000 m. the experiment will involve no contamination risks, and that the waste is only slightly radioactive.

Along with dumping at sea, Euratom is to examine various other methods of disposing of radioactive waste, for instance, underground in caves and tunnels.

## Reactor achieves boiling

The boiling heavy water reactor of the Norwegian Institutt for Atomenergi at Halden, the first reactor of this type in the world, which is being operated as a joint undertaking of the O.E.E.C. European Nuclear Energy

£ s d

### CHEMICAL PLANT COSTS

Cost indices for the month of October 1960 are as follows:

Plant Construction Index: 181.0

Equipment Cost Index: 169.0

(June 1949 = 100)

£ s d



Agency, achieved boiling recently. During this first boiling experiment the reactor power, which will ultimately be 20,000 kW, was brought up to 2,000 kW.

The reactor, moderated and cooled with heavy water, and using an initial fuel charge of natural uranium, first went critical in June 1959. The first part of the experimental programme, comprising a series of low-power tests to obtain information on reactor physics parameters, was finished last January. The reactor was then shut down for routine checks and modification work necessary before continuous power operation, and was brought critical again in August.

The reactor was designed at the Netherlands-Norwegian Joint Establishment for Nuclear Energy Research, Kjeller, and was built by the Norwegian Institutt for Atomenergi.

#### Atoms-for-Peace grant

The Government of Denmark has received \$350,000 from the Government of the U.S. toward the cost of a research reactor constructed for the Danish Atomic Energy Commission.

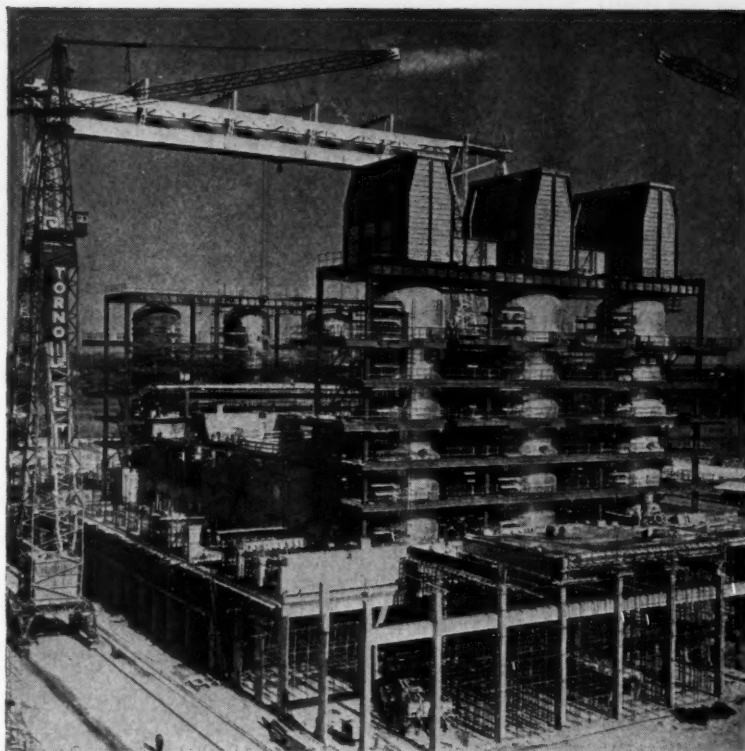
Denmark is the fifth country to receive from the U.S. payment of a \$350,000 research reactor grant under the Atoms-for-Peace programme to assist friendly countries in developing nuclear research and in providing facilities for the training of scientists and engineers. Payment is made upon completion of the reactor project. Other countries receiving payments of the grants are Brazil, Federal Republic of Germany, Spain and Italy.

The reactor, a 5-MW tank type, using light water as a coolant and moderator, is part of the Danish Atomic Energy Commission's nuclear centre at Riso, about 20 miles west of Copenhagen.

#### Film on Hinkley Point

Two years' work in designing and building the 500,000-kW atomic power station at Hinkley Point, for the U.K. Central Electricity Generating Board, are covered in a colour film, which shows the co-ordination of civil, mechanical and electrical engineering resources to carry through a major, pioneering project in the new field of nuclear power generation.

Construction began with the making of access roads, with site exploration in the fields and on the sea-bed, and with the reconstruction of the old Roman port at Combwich, five miles from the site, to bring in by sea over



The six heat exchangers in position at Latina nuclear power station in Italy. The design for these vessels was supplied by Head Wrightson & Co. and manufactured in Italy by Nuovo Pignone. The power station is being built by the Nuclear Power Group of Knotsford

30,000 tons of heavy equipment to be assembled at the site.

Three companies, English Electric Ltd., Babcock & Wilcox Ltd. and Taylor Woodrow Ltd. (the Atomic Power Group), with experience in electrical power generation, steam generation, mechanical and civil engineering, pooled the knowledge and techniques they had already acquired in the field of atomic power. Research and development work is shown by design and performance studies in the group's laboratories, including the use of modern electronic computers, both analogue and digital.

Animated diagrams explain the principles of atomic power generation and the improvement of efficiency by means of a dual-pressure steam cycle and by the steam turbine design. Main features of the Hinkley Point station are shown on a model.

#### Radioisotope conference

The International Atomic Energy Agency's radioisotope conference in Copenhagen made it clear that isotope applications are not only growing in variety but also rapidly emerging from the stage of officially sponsored re-

search and experiment to that of industrial practice. The resulting change in industrial technology is of more than purely technical interest; in some of the advanced countries it has already benefited industry to the extent of millions of dollars.

Methods of prospecting for ore and coal deposits with the help of radioisotopes were described at the conference by three Soviet scientists, who explained how the use of a radioactive source introduced in borehole logging and the measurement of the radiation reflected back to a detector indicated the depth of occurrence and thickness and structure of coal seams. There was also an account of methods of using radioactive hydrogen for determining the flow of water in an oilfield.

Scientists from a British petroleum research group reported on methods of using radioisotopes for measurement of the sulphur content in refinery streams which has to be kept below certain levels to give satisfactory products. Continuous measurement by radioisotope techniques would offer financial reward to oil refineries which are at present dependent on relatively slow measurements in the laboratory.

**DECEMBER 7** First annual conference on welding standardisation to be held at the Institute of Welding, 54 Princes Gate, Exhibition Road, London, S.W.7. The theme will be the role of welding standardisation in production and export.

**DECEMBER 12 TO 14** Winter meeting of the American Nuclear Society, including conference on **hot laboratories and equipment and the Atomic Industry Exhibition**, in San Francisco, California, U.S.A. Organised by the American Nuclear Society. Details from the secretary of the society, Mr. O. du Temple, c/o John Crerar Library, 86 East Randolph Street, Chicago 1, Illinois, U.S.A.

**DECEMBER 13** Lecture on **radiation effects on rubbers** to be held at 5.30 p.m. at the Royal Overseas League, Park Place, St. James's, London, S.W.1. Details from Institution of Rubber Industry, 4 Kensington Palace Gardens, London, W.8.

#### Of interest to our readers . . .

A number of articles appearing in our associate journals this month will appeal to readers of **CHEMICAL & PROCESS ENGINEERING**.

**Manufacturing Chemist**—Special feature on heat exchangers. Pressure-packed Pharmaceuticals, by P. W. Sherwood. Carbohydrates in the Chemical Industry, by G. Machell. Organon's new pharmaceutical factory in Holland.

**Paint Manufacture**—Recent Advances in Use of Epoxide Resins, by R. J. Turner and J. O. Ranger. Commercial Aspects of Water-thinned Paints, by A. Tremain. Advanced Paint Chemistry—13, by P. M. Fisk.

**Automation Progress**—Simplified Nuclear Reactor Simulation, by T. I. Canning. Self-organising Systems, by G. Pask. Circuit Blocks and Initial Design, by C. A. Clark.

**World Crops**—Feeding the World's Millions, by N. Wright. Aerial Spraying of Rubber, by P. de Jong.

**Dairy Engineering**—Manufacture of Instant Powdered Milk by C. W. Hall and T. I. Hedrick. Psychrophilic Bacteria on Pasteurised Milk, by S. B. Thomas.

**Food Manufacture**—Special feature on milk processing machinery.

**Petroleum**—Report on Milford Haven petroleum refinery. Sizing of Vapour-relieving systems, by J. Conison. Symposium report on quality control.

**DECEMBER 14 TO 16** Annual conference of the **Atomic Industrial Forum**. Information from the forum, 3 East 54th Street, New York, 22.

**DECEMBER 15** Meeting of the nuclear energy group of the Institution of Mechanical Engineers on the **impact of a three-fuel economy**. Details from the Institution, 1 Birdcage Walk, London, S.W.1.

**DECEMBER 15** Annual dinner of the **Institution of the Rubber Industry** to be held at the Savoy Hotel, London. Details from the Institution, 4 Kensington Place Gardens, London, W.8.

**DECEMBER 15 TO 16** Meeting of the **Powder Metallurgy Joint Group** of the Iron and Steel Institute to be held at Church House, Great Smith Street, London, S.W.1. Details from the group secretary, 17 Belgrave Square, London, S.W.1.

**JANUARY 12** Lecture on **metallurgical research at high pressures** to be given by Dr. J. E. Hilliard, of the Research Laboratory of U.S. General Electric Co., at 6.30 p.m. at the Institute of Metals, 17 Belgrave Square, London, S.W.1.

**JANUARY 12 TO 13** Course on the **disposal of waste from the uses of radioisotopes** to be held at the Manchester College of Science and Technology. Details from the Registrar, College of Science and Technology, Manchester 1.

**JANUARY 18 TO 19** Symposium on **pressure vessel research towards better design** organised by the Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

**JANUARY 24** Lecture on **mass transfer in drops and bubbles** at the Geological Society, Burlington House, London, W.1, at 5.30. Details from the Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

**FEBRUARY 6 TO 17** Practical course in **radiation safety and health physics** at the Liverpool College of Technology. Details from J. W. Lucas, College of Technology, Byrom Street, Liverpool 3.

**FEBRUARY 6 TO 17** Practical course in **radiochemistry — continuation of reactor technique and application of isotopes** course to be held in Karlsruhe, Germany. Details from Kernreaktor Bau- und Betriebsgesellschaft mbH., Weberstrasse 5, Karlsruhe, Germany.

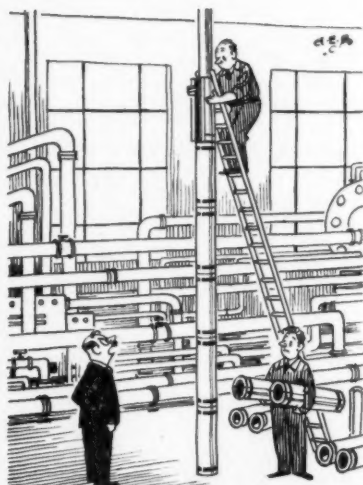
**FEBRUARY 15** Lecture on **science and the developing countries** by Prof. Blackett at the Geological Society, Burlington House, London, W.1. Details from the Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

**FEBRUARY 20** Lecture on **controlled fusion reactions** by Prof. Blackett organised by the Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

**FEBRUARY 20** Meeting of the nuclear energy group of the Institution of Mechanical Engineers on the **influence of availability of enrichment on reactor type and design**. Details from the Institution, 1 Birdcage Walk, London, S.W.1.

**MARCH 1** Symposium on **user experience of large-scale industrial vacuum plant** organised by the Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

#### COMICAL ENGINEERING CORNER



"DON'T BOTHER INSULATING THAT ONE, HOPKINS—IT MERELY HOLDS THE ROOF UP."

# CHEMICAL & PROCESS ENGINEERING

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